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ERRATUM

P. 156, in Table XVIII, at bottom of left-hand column: *for* "Early January" *read* "Early February".

[*Discovery Reports. Vol. IX, pp.* 1–64, *February*, 1934]

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HYDROLOGY OF THE BRANSFIELD STRAIT

By

A. J. CLOWES, M.Sc., A.R.C.S.

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HYDROLOGY OF THE BRANSFIELD STRAIT

By A. J. Clowes, M.Sc., A.R.C.S.

(Text-figs. 1–68)

MATERIAL

The hydrographic material on which this report is based was obtained from a series of stations made by the ships of the Discovery Committee in the Bransfield Strait and in the adjacent sea. The observations used were taken in April 1927, February 1929, November 1929 and December 1930, and are summarized as follows:

Table I

Stations	Date	
196–200	iv. 1927	King George Island to Trinity Peninsula
202–206	iv. 1927	Livingston Island to Trinity Peninsula
WS 382–WS 388	ii. 1929	King George Island to Trinity Peninsula
WS 389–WS 393	ii. 1929	Livingston Island to Trinity Peninsula
WS 395–WS 398	ii. 1929	Brabant Island to Low Island to Smith Island
WS 476–WS 482	xi. 1929	King George Island to Trinity Peninsula
WS 483–WS 487	xi. 1929	Livingston Island to Trinity Peninsula
WS 488–WS 491	xi. 1929	Brabant Island to Low Island to Smith Island
537–541	xii. 1930	Elephant Island to Joinville Island
542–547	xii. 1930	Cape Melville, King George Island, to Trinity Peninsula
549–553	xii. 1930	Snow Island to Trinity Island

In addition to the above lines of stations, odd stations, taken at varying times in the Bransfield Strait and de Gerlache Strait, have been used in the construction of the horizontal sections. The positions of all stations used are plotted in Fig. 1. Ice data have been obtained from our own observations, from a collection of ice reports made by Mr Risting of the Norwegian Whaling Association, and very largely by the kind help of Mr Nielsen of the Hector Whaling Company, whose personal experience of the Bransfield Strait has been of great value to us.

INTRODUCTION AND BATHYMETRIC FEATURES

The Bransfield Strait is a long, narrow strip of water approximately 70 miles wide, whose general direction lies north-east and south-west. It is bounded on the north-west side by the various islands of the South Shetland group, and on the south-east side by Graham Land and Trinity Peninsula, which together form the most northerly part of the Antarctic Continent. Fig. 1 shows the position and extent of the Bransfield Strait with its boundaries.

Many expeditions have visited and made hydrographic investigations in this area. The Expédition Antarctique Belge in the S.Y. 'Belgica' crossed the southern end of the Bransfield Strait, passing between Snow Island and Smith Island to de Gerlache Strait on the way to the Bellingshausen Sea in January 1898. The first expedition to do any considerable hydrographical work in the Bransfield Strait itself was the Swedish South Polar Expedition in 1901–3. The Deuxième Expédition Antarctique Française in 1908–10 also worked in and south of the Bransfield Strait. Later the German Atlantic Expedition, 1925–7, visited the area in January 1926 and was the first expedition to use echo-sounding. Since March 1927 very considerable work has been done in the Bransfield Strait and the neighbouring seas by the various ships of the Discovery Committee, i.e. the R.R.S. 'Discovery', the R.R.S. 'William Scoresby' and the R.R.S. 'Discovery II'. Altogether over a hundred stations have been taken by these ships in the Bransfield Strait area. The soundings at these stations, mostly obtained by use of the Lucas sounding machine, have been considerably augmented by over 1400 echo-soundings taken by the R.R.S. 'Discovery II'. Thus by combining all the information at hand a fairly accurate bathymetrical chart can be drawn of this area; it

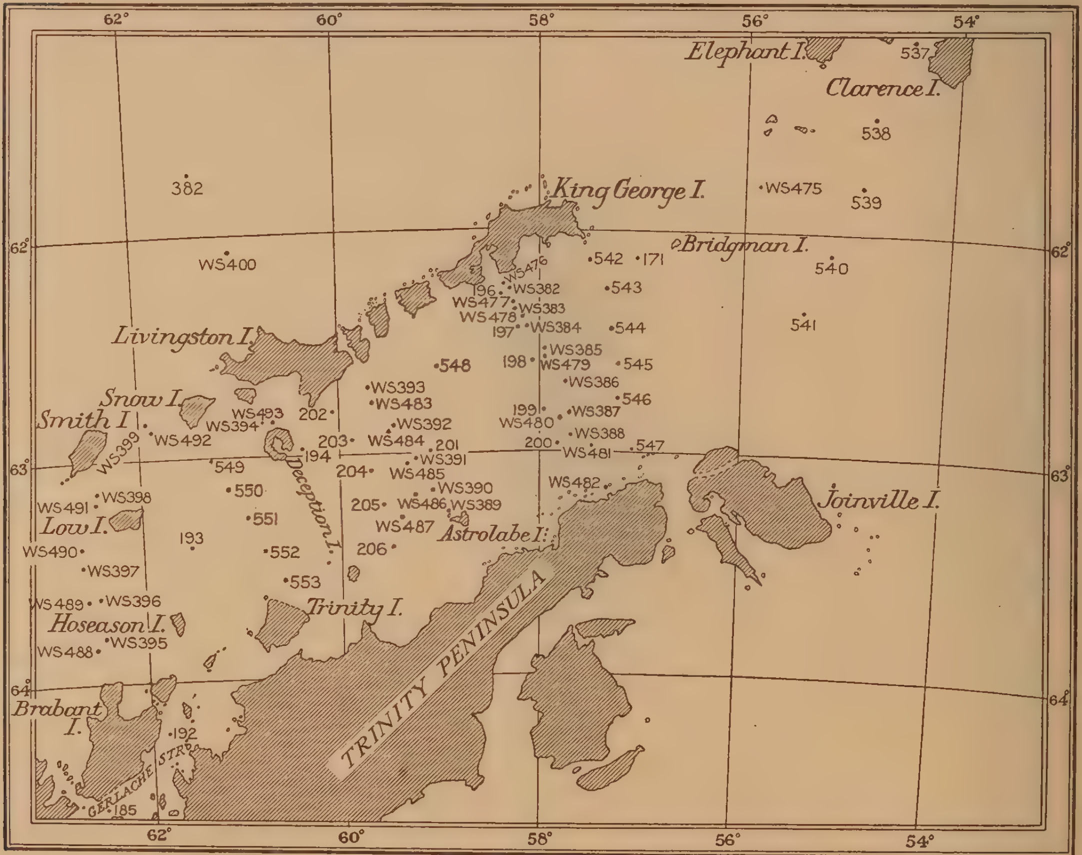

Fig. 1. Chart of the Bransfield Strait showing positions of stations.

is shown in Fig. 2.[1] It will be seen that the contours of the sea-bottom in the Bransfield Strait are very irregular, but the soundings show that the strait itself is practically cut off on all sides by land masses or by submarine ridges which will be described later. Since soundings of over 2000 m. are recorded and confining ridges, varying between 600 and 250 m. in depth from the surface, have been discovered, it follows that the Bransfield Strait consists of a deep basin shut off on all sides. These ridges restrict the deep water in the Bransfield Strait from contact and free circulation with that of the seas outside. This has a marked effect on the temperature of the water in the Strait below the level of these submarine ridges. The existence of very low temperatures in the water below 300 m. has been noted by many expeditions, and the probable existence of submarine ridges has been postulated by reason of the presence of these temperatures, taken in conjunction with the few soundings available before echo-sounding was used. Thus O. Nordenskjöld (1917, p. 9): "Deuten also schon die Lotungen an, dass hier ein allseitig abgesperrtes Tiefenbecken vorliegt, so wird dies in eklatanter Weise durch die Messungen der Wassertemperaturen bestätigt, und

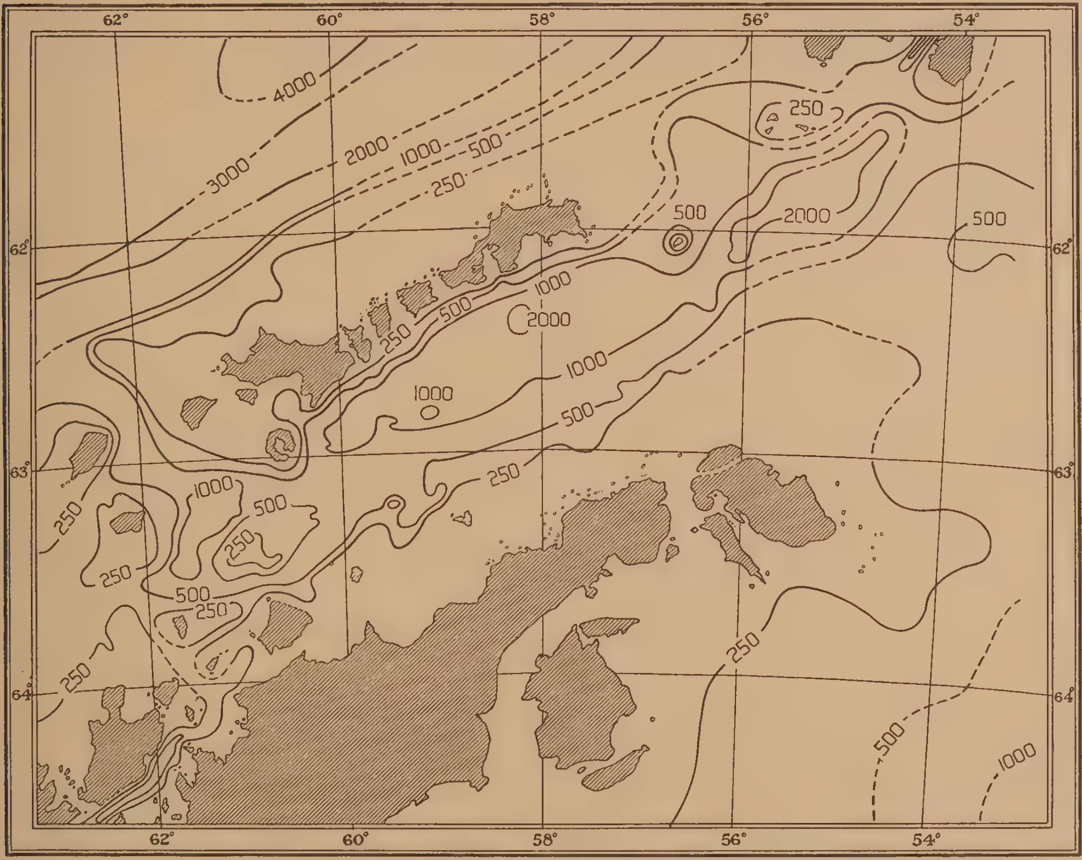

Fig. 2. Bathymetric chart of the Bransfield Strait. Soundings in metres.

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[1] This chart is based on that published by Herdman, 1932, pl. xlvii.

schon J. G. Andersson zog aus der gefundenen Bodentemperatur von – 1·6° bis – 1·8° diese Schlussfolgerung". Similarly J. Rouch (1913, p. 28): "...à partir d'une profondeur voisine de 500 mètres, la température de l'eau de mer est constante et assez basse, ce qui laisse supposer que le détroit de Bransfield forme un bassin spécial fermé par un seuil dont la profondeur serait voisine de 500 à 600 mètres". Also G. Wüst (1926, p. 243): "...das Bransfield-Meer. Dieses abgeschlossene Meeresbecken, dessen grösste Tiefe wir auf unserem Kurse mit etwa 2000 m. feststellten, ist unterhalb 300 m. mit einem sehr kalten und fast homohalinen Wasser erfüllt, das offenbar an den Böschungen des Graham-Landes abgesunken ist. Der Temperaturunterschied korrespondierender Tiefen innerhalb und ausserhalb des Beckens erreicht in 1000 m. den hohen Betrag von 3·05°".

In February 1929 the R.R.S. 'William Scoresby' observed a temperature of 1·11° C. at 1500 m. at St. WS 400, in 62° 07′ S, 62° 33′ W, i.e. just outside the strait, whilst 5 days previously at St. WS 385, inside the strait at 62° 32′ S, 57° 55′ W, a temperature of – 1·63° C. was recorded at the same depth.

The above comments or results from four different sources show the very great connection between the contours of the sea-bottom of this area and the peculiar hydrographical conditions to be found there.

Previous to the echo-sounding work of the German Atlantic Expedition in 1926 and the soundings taken during the Discovery investigations in 1927, 1929, 1930 and 1931, the bathymetric chart published in 1917 by O. Nordenskjöld was probably the most accurate. The Swedish South Polar Expedition in 1901–2 had taken a line of soundings between McFarlane Strait and Astrolabe Island, some soundings on the continental shelf of Graham Land and some soundings to the north-east of the Bransfield Strait. These soundings showed the presence of a longitudinal basin which was closed at the north-east end by a rise of the sea-bottom to the common shelf depth of 400–500 m., to fall again rapidly on the eastern side to the great ocean depths. The Deuxième Expédition Antarctique Française, 1908–10, confirmed the existence of the basin in the Bransfield Strait. The echo-soundings of the German Atlantic Expedition, 1925–7, showed the rise of the continental shelf of the South Shetland Islands from the great ocean depths of the Drake Strait. According to O. Holtedahl (1929, p. 95) these soundings of the German Atlantic Expedition showed the existence of very marked planes of abrasion, thus proving a former higher level of the land and consequently an increased width of the South Shetland Islands in the past. The echo-soundings of the 'Meteor' again showed the presence of a deep basin in the Bransfield Strait, with an indication of a rise in the sea-bottom to the north, some 13 miles west-south-west of Elephant Island and approximately 12 miles north of Aspland Island.

Such was the state of knowledge when our own observations began. Lines of stations from King George Island and Livingston Island across the strait to Trinity Peninsula, and between Smith Island and Brabant Island were worked in 1927, 1929 and 1930, and the sounding data from these stations were augmented by over 1400 echo-soundings in this area by R.R.S. 'Discovery II'. In the bathymetric chart, Fig. 2, all the above information and as much of the older information as possible has been used.[1]

At the south-west end of the Bransfield Strait lie the islands of Snow, Smith, Low, Hoseason, Intercurrence, Brabant, Trinity and Deception. The soundings show that these islands are connected by submarine ridges with different saddle-depths. To the east of Smith Island a channel of greater depth than 600 m. occurs, which connects with the south-west basin of the Bransfield Strait. A channel, possibly deeper than 500 m., may occur south of Low Island, also giving access to the south-west basin which is described later. Between Snow Island and Deception Island the depth is nowhere greater than 250 m., although between the latter island and Livingston Island a depth of over 500 m. exists. The submarine ridge between Deception and Trinity Islands has a saddle-depth of probably between 700 and 800 m. There is also a possibility of a slightly increased depth near Trinity Island. However, in the area contained by the triangle formed by the islands of Deception, Low and Hoseason, depths between 1300 and 1400 m. are recorded. Thus at the south-west end of the Bransfield Strait a basin is present whose boundaries are the islands and ridges connecting the islands of Snow, Smith, Low, Hoseason, Trinity and Deception, and whose greatest depth is probably not more than 1400 m.

The second and larger basin in the Bransfield Strait runs south-west and north-east. It begins at the shoal on which Deception Island stands, and continues until that of Clarence Island is reached. A slight constriction of its width occurs south-south-east of Bridgeman Island where the sea-bottom rises to a depth of 1200 m. from the surface; on both north-east and south-west sides depths greater than 2000 m. are reached. This basin lies closer to the South Shetland Islands than to Trinity Peninsula and Graham Land owing to the steepness of the very narrow continental slope on the south-east side of the South Shetlands, and the more gentle sloping of the extensive continental shelf on the coast of Graham Land and Trinity Peninsula. At the north-east end of this basin there is evidence of two confining submarine ridges. To the north the 'Meteor' obtained an echo-sounding of 199 m. some 13 miles approximately west-south-west of Elephant Island, whilst the R.R.S. 'Discovery II' on a course just west of north in the gap between Elephant Island and King George Island obtained gradually diminishing echo-soundings with a minimum depth of 223 m. at 61° 14′ S, 56° 39′ W. Thus there is some evidence for assuming the existence of a continuous continental shelf between Elephant and King George Islands. To the *east* the wide continental shelf north of Joinville Island in the direction of Clarence Island has been shown to be considerably extended and a large area of just over 300 m. was found by echo-soundings. Thus to the east of the Bransfield Strait there is also some evidence of a submarine ridge between Clarence and Joinville Islands, with the saddle-depth a short distance south of the former island. Many more soundings in this area are necessary before the bottom contours at the northern end of the strait can be drawn accurately. For a more detailed description of the soundings in the Bransfield Strait reference should be made to the paper on soundings by H. F. P. Herdman (1932).

---

[1] It is to be noted that a number of the earlier soundings cannot be plotted on recent charts. Surveys undertaken during the course of our work have shown that the existing charts were inaccurate, and though much still remains to be done, especially off Trinity Peninsula, the coast-line of some part of the South Shetlands has been corrected and the positions of a number of the islands have been revised. The corrections have been incorporated in the latest Admiralty charts. A number of the early soundings were fixed by land bearings, and they cannot be transferred to the new charts unless the original data are available.

Thus the Bransfield Strait consists of two basins enclosed by shelves of the South Shetland Islands, Elephant and Clarence Islands, Graham Land and Trinity Peninsula and by submarine ridges at either end of the strait. The effect of these ridges is to restrict the horizontal circulation of the water masses which lie below the depth of the confining ridges.

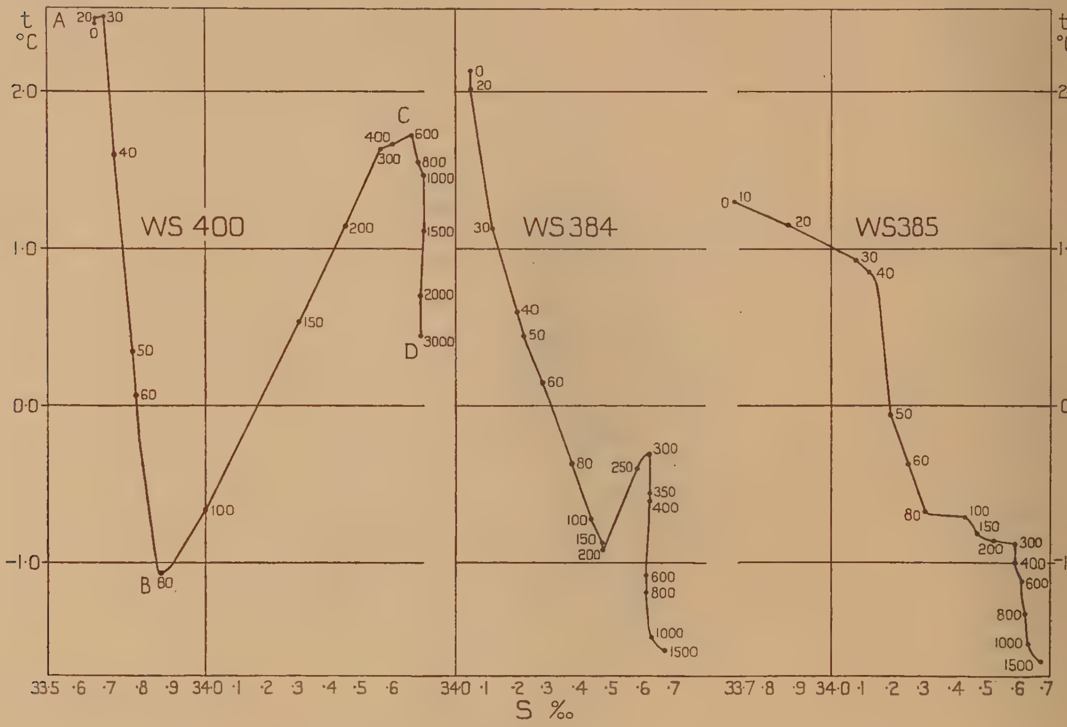

Fig. 3. Temperature-salinity diagrams for Sts. WS 400, WS 384 and WS 385.

Before discussing the hydrology of the Bransfield Strait and the manner in which it is influenced by the topography of the sea-bottom, the following comparison of conditions inside and outside the strait will be of service. For this purpose three stations from February 1929 have been selected: St. WS 400 situated in 62° 07′ S, 62° 33′ W, i.e. in the Drake Passage just north of the Bransfield Strait, and Sts. WS 384 and WS 385, situated both at the north-east end of the strait in 62° 25′ 40″ S, 58° 06′ 10″ W and 62° 32′ S, 57° 55′ W respectively. The temperature and salinity data from these stations have been plotted in Fig. 3 as temperature-salinity diagrams. The figures on the curves represent the depths in metres of the observations.

In the Antarctic Zone of the South Atlantic Ocean the water masses may be divided into three layers. The uppermost consists of Antarctic surface water, the middle layer of warm deep water and the lowest layer of Antarctic bottom water. The effect of the relatively warmer middle layer is to produce a temperature inversion below the cold nucleus of the surface layer.

If we consider firstly the temperature-salinity curve for St. WS 400 it can be seen that it consists of three distinct portions *AB*, *BC* and *CD*. The line *AB* represents the effect of summer conditions on Antarctic surface water, which has come from the Bellingshausen Sea and has been warmed by the sun and diluted by melting ice in its upper portion. The point *B* represents the relation of temperature and salinity at the cold nucleus of this layer. Between *B* and *C* both the temperature and salinity increase rapidly with depth and this portion of the curve represents the mixtures between these depths of Antarctic surface water and warm deep water, the latter water being of Pacific origin. At *B* only Antarctic surface water and at *C* only warm deep water is present and the proportion of each type of water in the mixture represented by the line *BC* may easily be calculated. From the point *C* the temperature commences to fall rapidly to the lowest observation and the salinity increases very slowly as far as 1000 m., where it remains constant until 1500 m., below which it decreases very slightly to the two lowest observations at 2000 and 3000 m. If the warm deep water were a homogeneous layer the portion *CD* would accurately represent the mixtures of this layer with Antarctic bottom water. The latter, however, does not commence to influence the salinity until a depth between 1500 and 2000 m. is reached. Thus only below 1500–2000 m. does the amount of Antarctic bottom water in the mixture commence to be appreciable. At this station there is a very smooth transition from the warm deep water to the bottom water of the southern part of the Drake Passage.

The temperature-salinity curve for St. WS 384 shows essentially the same features as that for St. WS 400, with, however, some modifications, due to the fact that St. WS 400 is situated outside and WS 384 inside the strait. The summer warming and dilution of the surface layer is seen between 0 and 200 m. The cold nucleus of the Antarctic surface water is, however, deeper than usual and the salinity at this point is high, which indicates the effect of vertical mixing in winter. Between 200 and 300 m. both salinity and temperature increase, but the temperature does not rise beyond – 0·31° C., which is found at 300 m. Compared with the corresponding temperature at St. WS 400 this temperature is 2·03° lower and is situated 300 m. nearer the surface. Thus a large difference is found in the temperature and depth of the maximum temperature of the warm deep water at stations inside and outside the Bransfield Strait. This is perhaps the chief effect of the topography of the sea-bottom of the strait. The flow of warm deep water into the strait is restricted by submarine ridges, and as a consequence the circulation with the warm deep water of the outside sea is greatly modified. At the majority of the stations inside the strait the temperature inversion due to the presence of the warm deep water is either absent or very weak. Between 300 m. and the lowest observation the warm deep water at St. WS 384 is mixed with increasing amounts of Antarctic bottom water until at 1500 m. the temperature reaches the low value of – 1·56° C.

St. WS 385 was selected as one of the many stations inside the Bransfield Strait at which no temperature inversion is present owing to the poor development of the warm deep water inside the strait. In the temperature-salinity curve for this station it is seen that the surface water has been warmed by the sun and considerably diluted. Between the surface and a depth of 40 m. the salinity increases rapidly, and from 40 to 80 m. the salinity increase is less rapid but the temperature decreases rapidly. Between 80 and 300 m. the salinity increases rapidly, but the temperature does not fall very much. This layer between 80 and 300 m. represents the effect of vertical mixing in winter, with the consequence that the salinity in this layer is less than at the corresponding depths in the two other stations, and all evidence of a temperature inversion has been eliminated.

The temperature-salinity curves for these three stations show a gradation from conditions in the outside sea to conditions inside the Bransfield Strait: in the latter the amount of warm deep water is greatly restricted, as is seen either by the small maximum temperature of this layer at some stations, e.g. St. WS 384, or by the complete absence of a temperature inversion at the majority of stations, e.g. St. WS 385. As a consequence of the decreased amount of warm deep water inside the strait the level of the Antarctic bottom water is much higher inside the strait than outside.

The restricting influence of the submarine ridges is especially pronounced in the low temperatures inside the strait below 300 m. In the Bransfield Strait only traces of the warm deep water from outside are present, and this water in very reduced amount is found mainly at the south-west end of the strait and at stations close to the south-east coast of the South Shetland Islands (except in November 1929), where the extent of its presence is shown by weak intermediate maxima in temperature. Farther towards the eastern part of the strait nearly all thermal trace of the warm deep water is missing. This is due to mixing with the highly saline and cold Antarctic water whose origin is the Weddell Sea; part of this water is carried round Joinville Island to flow across the strait at its northern end, and some down it in a south-westerly direction on the Trinity Peninsula side of the strait. The maximum temperature of the warm deep water, which in the adjacent sea is found near the upper surface of this layer at approximately 500 m., is situated inside the strait at least 100–200 m. nearer the surface.

The bottom water from the deep ocean outside the strait cannot enter the Bransfield Strait because of the submarine ridges. Even in the great depths of the Drake Passage and the Weddell Sea the temperature never approaches the low value of − 1·72° C., which has been found inside the Bransfield Strait at a depth of 1500 m. The bottom water inside the strait is essentially formed within the strait.

HORIZONTAL AND VERTICAL SECTIONS OF TEMPERATURE, SALINITY AND DENSITY

APRIL 1927

From the results obtained in April 1927 a more complicated system of water layering was sometimes found than had hitherto been observed by us in the south-west Atlantic south of the Antarctic convergence. Three layers of water are usually found in these latitudes, Antarctic surface water, warm deep water and Antarctic bottom water. In the Bransfield Strait the layering is often more complicated, although the warm deep layer is frequently absent. Factors introduced by the presence of ice and its melting, and by the cooling and intense vertical mixing in winter, give rise to patches of old water which appear out of place in the vertical column as reflected particularly by the vertical temperature series. Unusual inversions of temperature and sometimes of salinity are seen at some stations. Close to Graham Land and Trinity Peninsula practically all trace of the warm deep water, as usually shown by an intermediate maximum in temperature at about 500 m. depth in the neighbouring sea, is absent.

Figs. 4–6 give the surface salinity, temperature and density (σ_t). Light water can be seen in the surface close to the South Shetland Islands, and heavier colder water spreading out from the north-west coast of Trinity Peninsula. The light water, which flows as a north-east going set, consists of Antarctic surface water from the Bellingshausen Sea, and as later surveys have shown, enters the Bransfield Strait between Smith Island and Snow Island and between Low Island and Smith Island. A branch of this stream is seen as an eastward set reaching approximately 35 miles south-east of Livingston Island, corresponding to the easterly set noted slightly more to the east of this position on the Admiralty chart of the area. The heavier colder water close to the Trinity Peninsula coast has its origin in the Weddell Sea; it has spread out round

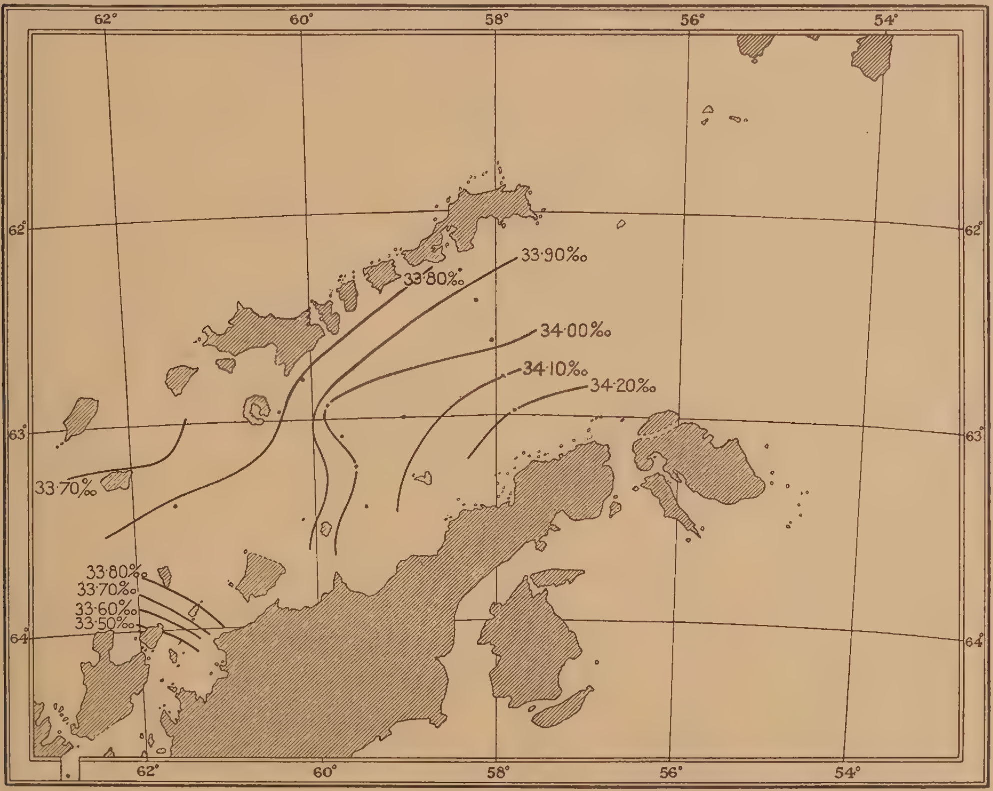

Fig. 4. Surface salinity: April 1927.

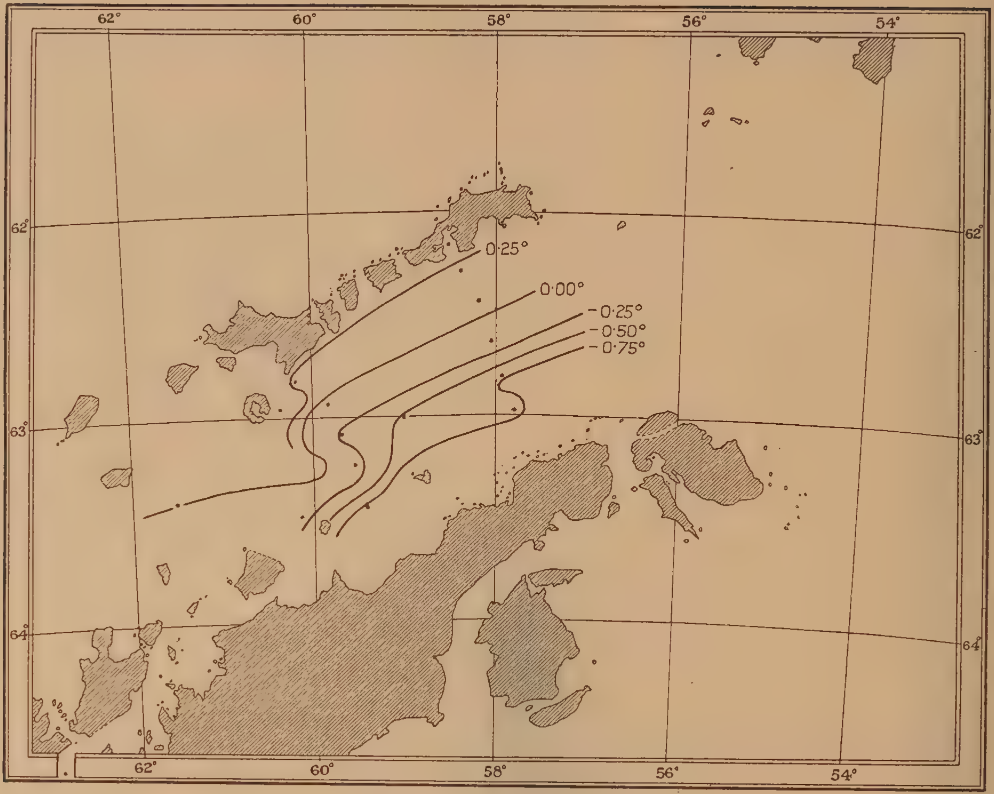

Fig. 5. Surface temperature: April 1927.

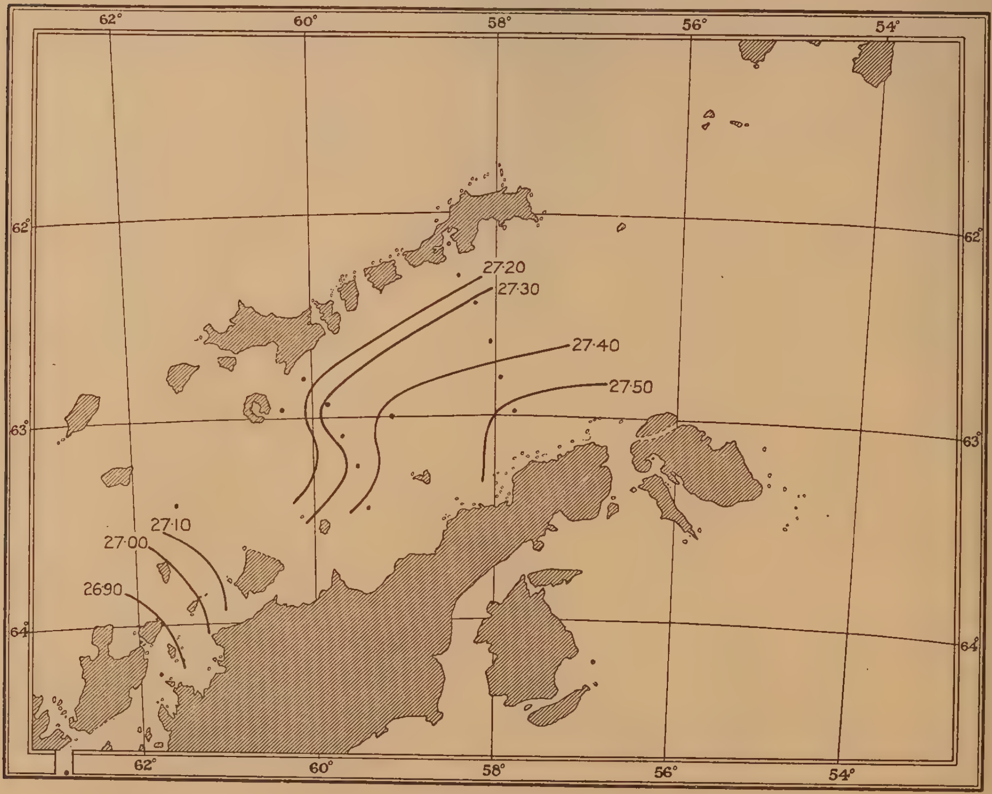

Fig. 6. Surface density (σ_t): April 1927.

Joinville Island and reaches about as far as Trinity Island, where it meets the slight north-east set from de Gerlache Strait in Orleans Channel between Trinity Island and Graham Land. The effect of the cold dense Weddell Sea water towards the north-east end of the Bransfield Strait and on the Trinity Peninsula side is such that all or practically all traces of the temperature inversion due to the warm deep water, which usually lies immediately below the colder Antarctic surface water, have disappeared from Sts. 197, 198, 199, 200, 201, 204, 205 and 206, which are enclosed in the shaded area in Fig. 7.

The difference between the water on either side of the strait is emphasized in this series of observations because the water on the north-west side of the strait has been warmed more by the sun than that on the south-eastern side, which is much colder and has its origin in the Weddell Sea. In winter this difference of temperature of the surface waters in these currents would not be shown to such an extent owing to surface cooling and vertical mixing. In midsummer in calm weather a discontinuity surface is sometimes found with a temperature difference of over 2° C. between the surface and a depth of 10 m.

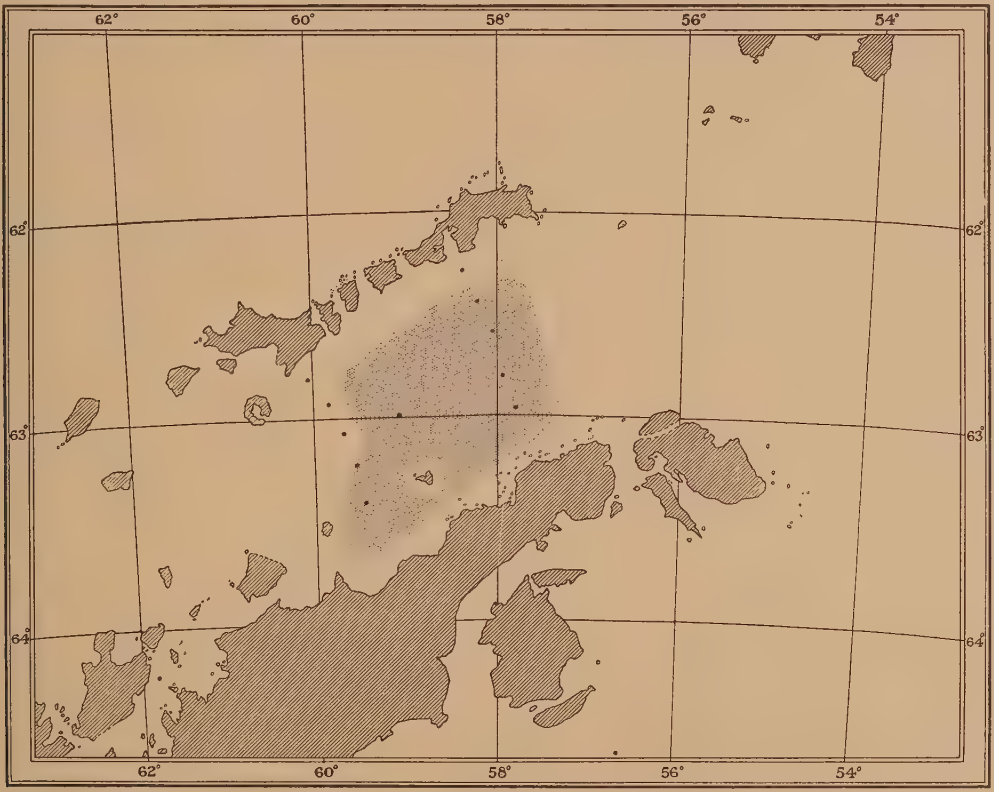

Fig. 7. The stippled patch shows the area in April 1927 in which no thermal evidence of the warm deep water was present.

Considerably less saline surface water is to be seen in and south-west of the de Gerlache Strait, and this water shows a very striking contrast with the heavy colder surface water farther to the north-east along the coast of Graham Land and Trinity Peninsula.

The vertical sections of the salinity, temperature and density (σ_t) of the line from King George Island to Trinity Peninsula are given in Figs. 8–10.[1] Near Trinity Peninsula the surface water consists of cold dense water forming part of the south-west set on this side of the strait. As King George Island is approached the surface water becomes warmer and less dense and forms part of the north-east going current which has entered the Bransfield Strait between Snow Island and Smith Island and between Low Island and Smith Island.

At St. 198, approximately 25 miles south-south-east of King George Island, the temperature and salinity of the water below 200 m. are lower than at corresponding levels at Sts. 197 and 199 on either side. From the shape of the lines of equal density and from dynamic analysis it appears that St. 198 is the centre of a circular motion, the water moving in opposite directions on either side of this station. The charts of dynamic topography show that the level of the surface of the sea at St. 198 is higher than at Sts. 197 and 199 on either side. The movement of water has a more or less constant velocity down to 200 m. at St. 198 and then decreases with depth. In a later part of this report considerable doubt is thrown on many of the temperature and salinity results of the line of stations from King George Island. In such an enclosed basin as the Bransfield Strait it is surprising to find so much horizontal circulation below 200 m. as

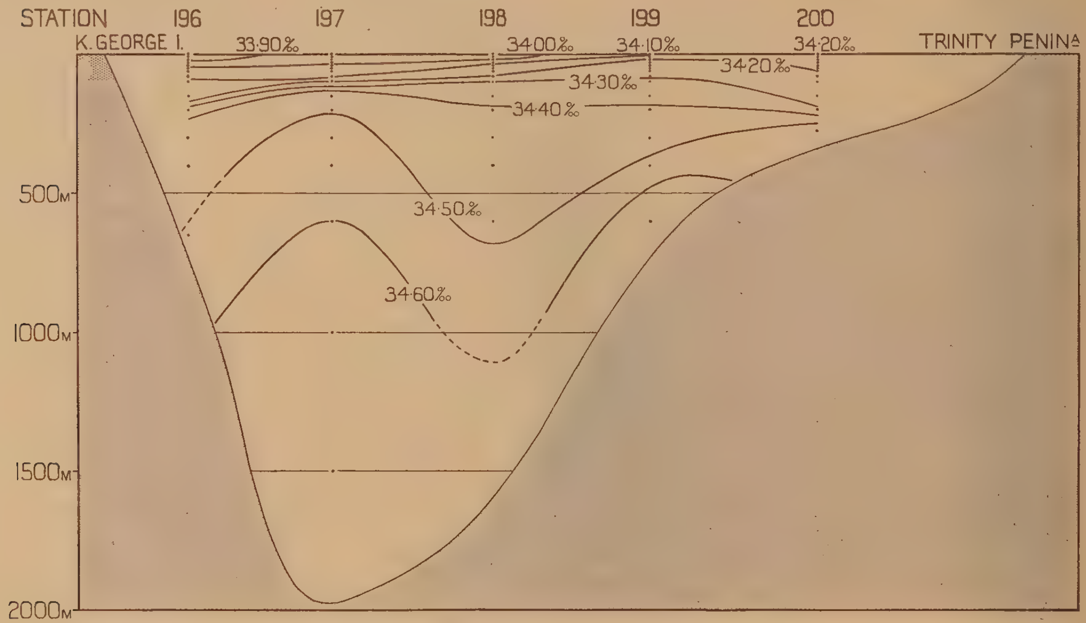

Fig. 8. Vertical section of salinity: King George Island to Trinity Peninsula, April 1927.

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[1] In considering these sections, some observations of salinity have been neglected, and in particular St. 197, 800 m., $35{\cdot}06\,^{\circ}/_{\circ\circ}$, St. 198, 1500 m., $34{\cdot}87\,^{\circ}/_{\circ\circ}$, and St. 199, 700 m., $35{\cdot}01\,^{\circ}/_{\circ\circ}$. It is considered that these salinities, abnormally high for the latitude, are due to the partial freezing of the sea water in the reversing water bottles before a sample could be taken, with the consequence that the salinity of the remaining water became considerably increased. During these particular stations air temperatures of – 7° to – 10° C. were recorded. All three salinities were the result of duplicate titrations.

is needed to account for the shape the lines of equal density assumed in April 1927.

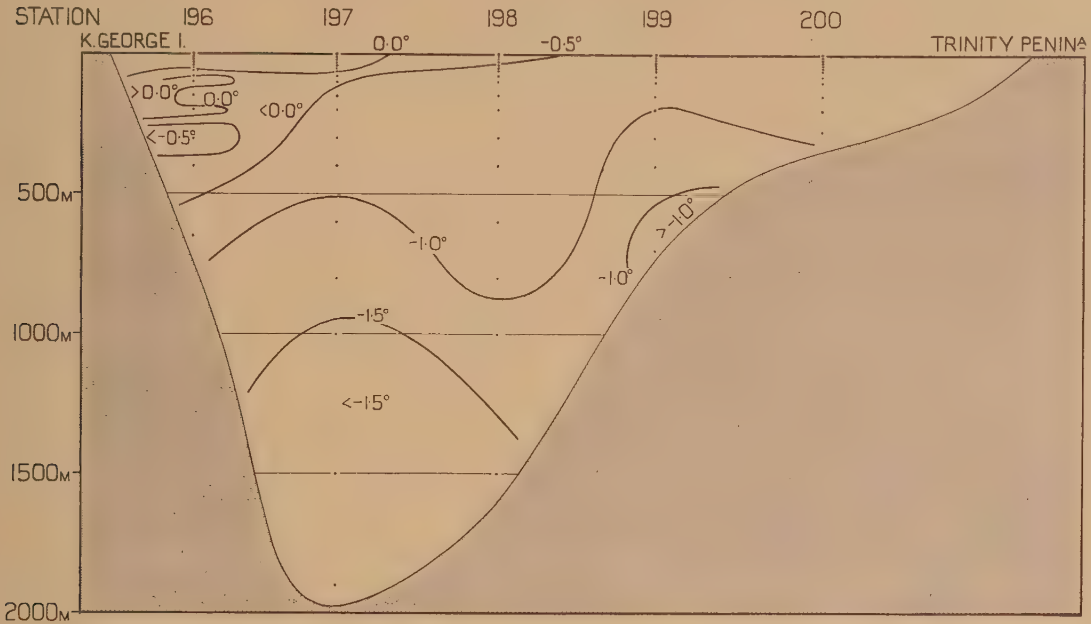

Fig. 9. Vertical section of temperature: King George Island to Trinity Peninsula, April 1927.

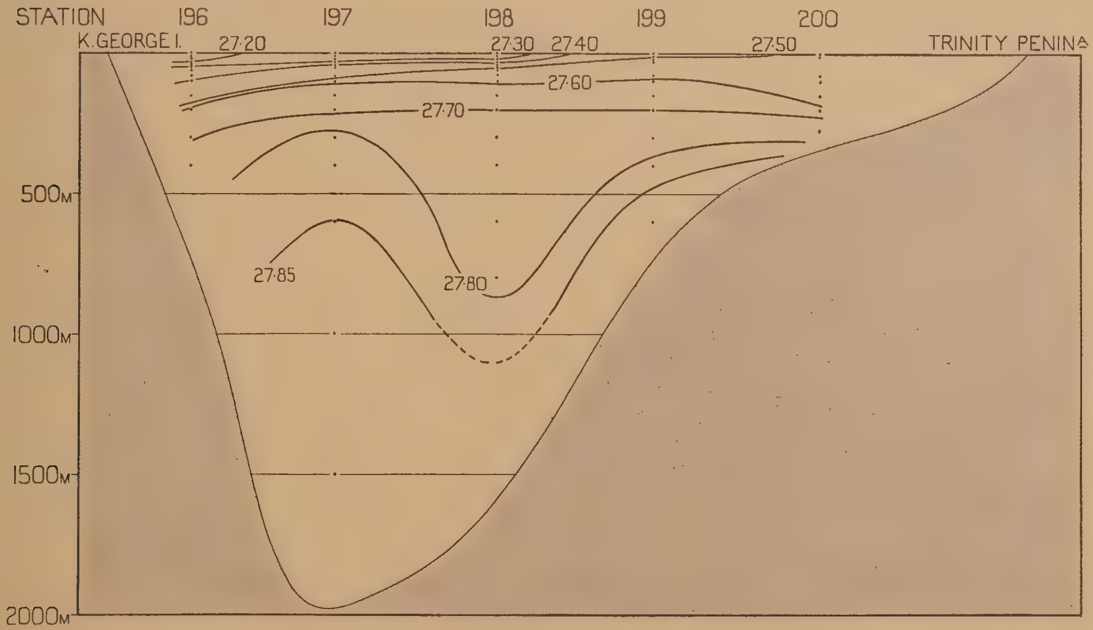

Fig. 10. Vertical section of density (σ_t): King George Island to Trinity Peninsula, April 1927.

The vertical temperature section shows the cold water at all depths at the north-east end of the strait and the slight trace of the warm deep water only at St. 196 closest to King George Island. The vertical salinity section shows the lower saline water below

200 m. at St. 198 which has already been noticed. In general the salinity of the deeper water in the Bransfield Strait is lower than at corresponding depths in the seas outside the strait. This is due to the effect of the bounding ridges surrounding the Bransfield Strait in restricting the flow of warm deep water into the strait and to the very considerable vertical mixing which occurs throughout the strait in winter. At depths below the traces of warm deep water inside the strait the water is formed from the dense water of Weddell Sea origin which mixes with the surface water in the remainder of the strait and in winter is rendered more saline by the removal of water in the form of ice. The more saline water then sinks to form the bottom water.

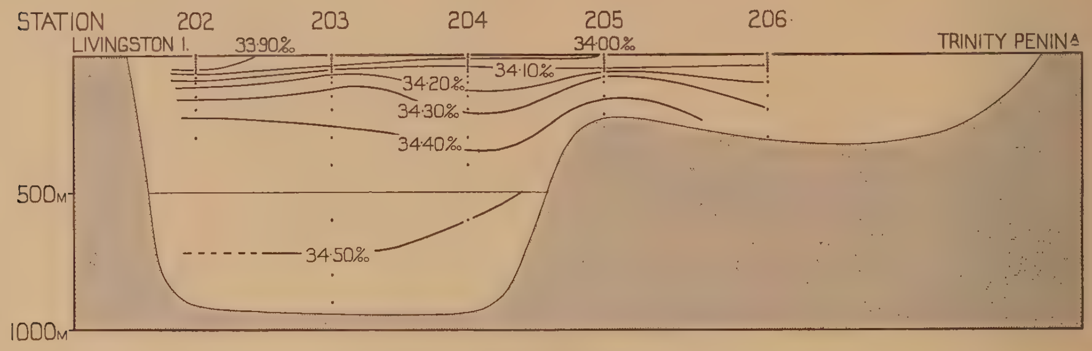

Fig. 11. Vertical section of salinity: Livingston Island to Trinity Peninsula, April 1927.

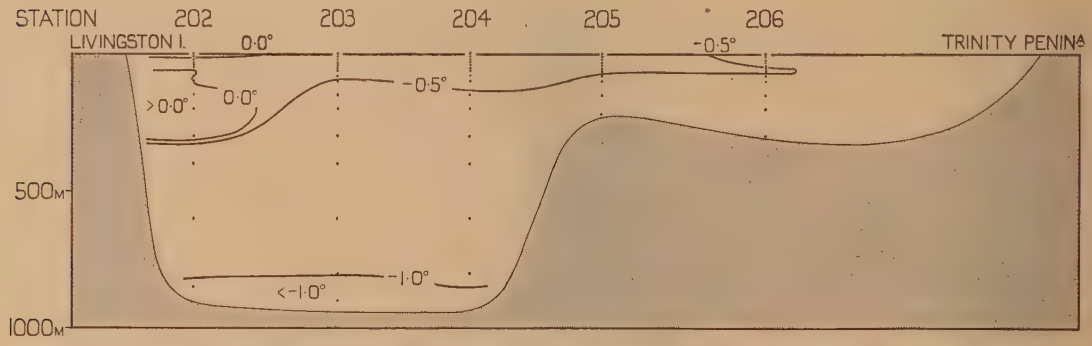

Fig. 12. Vertical section of temperature: Livingston Island to Trinity Peninsula, April 1927.

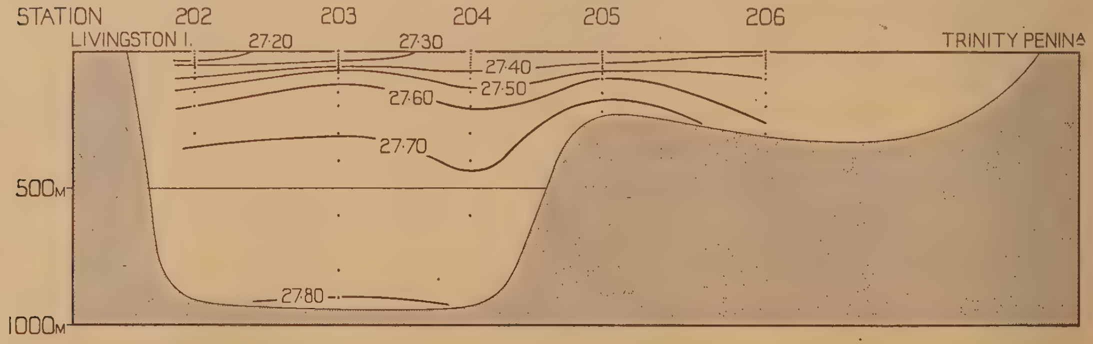

Fig. 13. Vertical section of density (σ_t): Livingston Island to Trinity Peninsula, April 1927.

The vertical sections of salinity, temperature and density (σ_t) for the line between Livingston Island and Trinity Peninsula are shown in Figs. 11–13. The surface salinity is least and the temperature highest at the station nearest Livingston Island. This station, 202, is in the north-east set and is the only station to show a positive temperature range below the surface water; at 300 m. it has an intermediate temperature maximum of 0·36° C. At the other stations barely a trace of a temperature inversion occurs below the surface and the influence of the warm deep water may almost be said to stop at St. 202. The water below 300 m. at all stations consists of a mixture of Antarctic surface water or warm deep water, as at St. 202, with increasing amounts with depth of Antarctic bottom water.

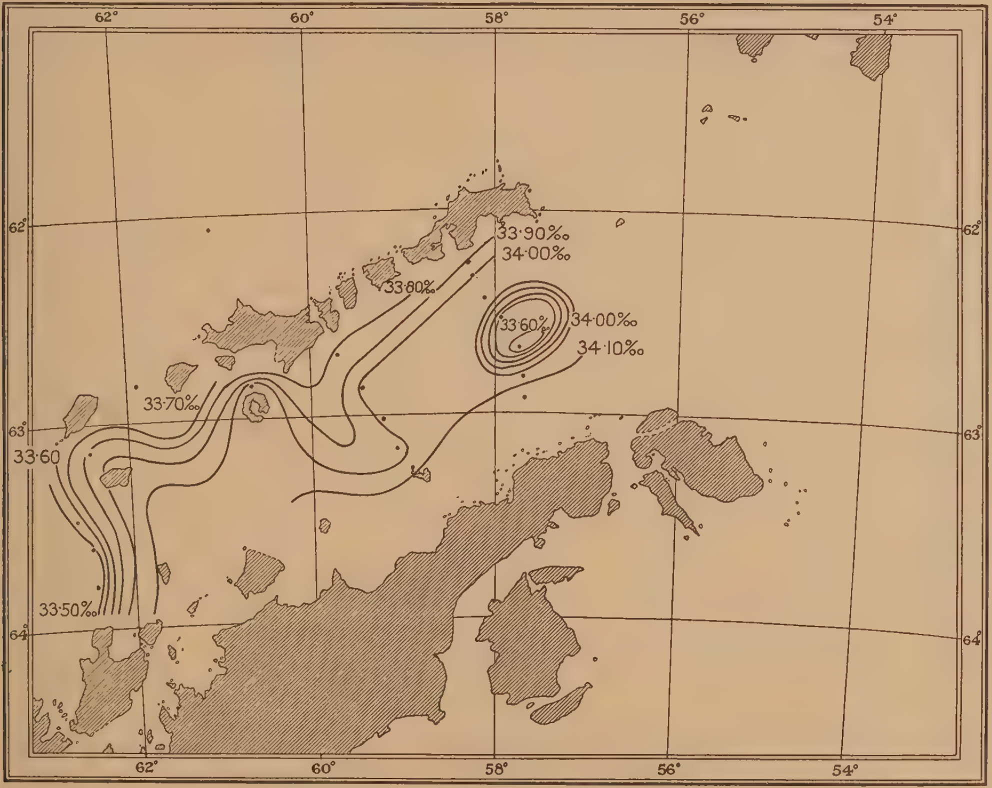

Fig. 14. Surface salinity: February 1929.

FEBRUARY 1929

The hydrological work in the Bransfield Strait which had been done in April 1927 by the R.R.S. 'Discovery' was repeated and augmented by the R.R.S. 'William Scoresby' in February 1929, when, in addition to repeating the lines of stations from King George Island and Livingston Island to Trinity Peninsula, a new line of four stations was made at the southern end of the strait from Brabant Island to Smith Island, with one station between the islands of Smith and Snow, and another between Livingston and Deception Islands. Figs. 14–16 show the distribution of the surface salinity, temperature and density (σ_t).

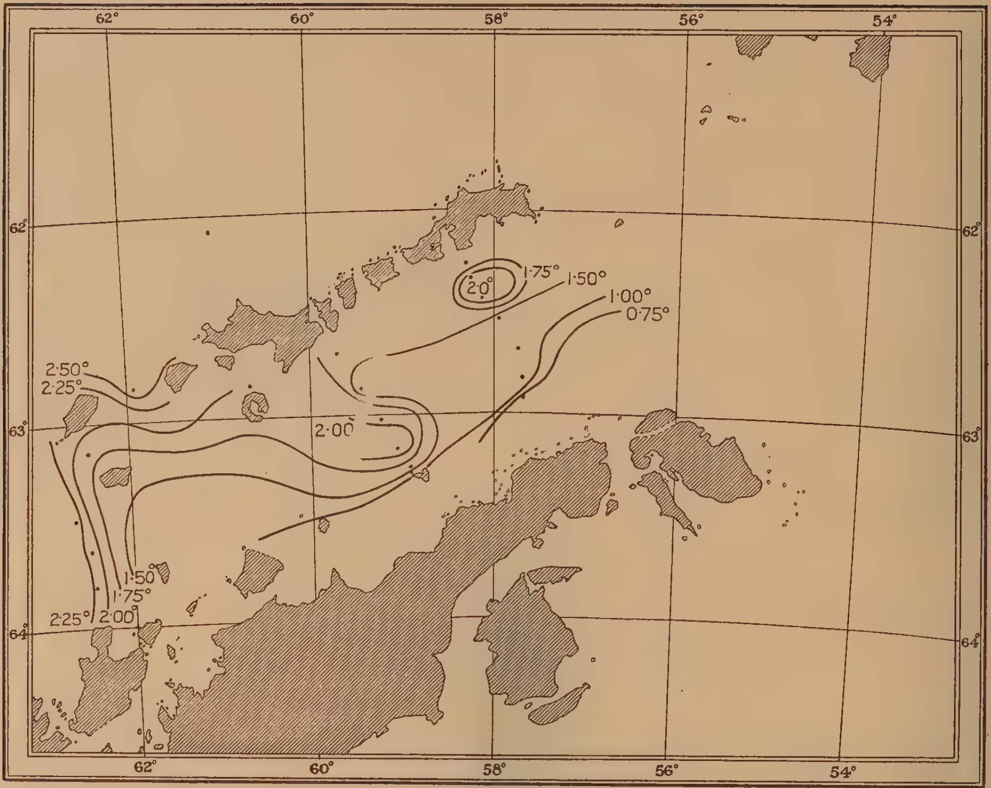

Fig. 15. Surface temperature: February 1929.

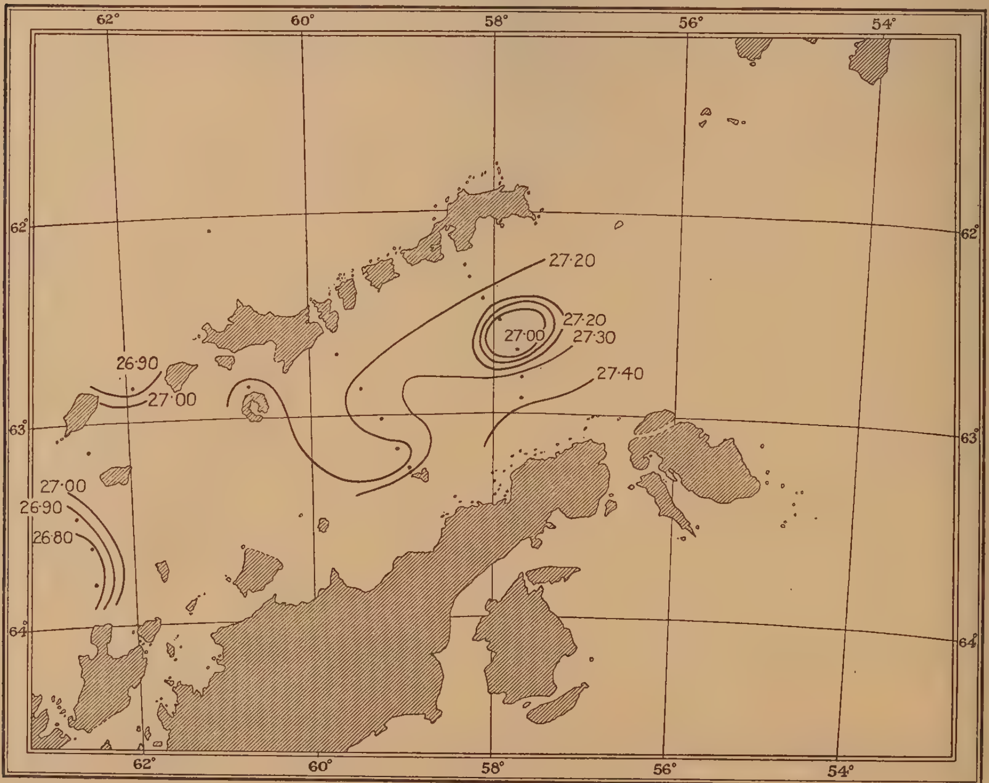

Fig. 16. Surface density (σ_t): February 1929.

The temperatures and salinities of the surface water at the stations in this survey show the effect of summer conditions in the Bransfield Strait. The surface water is probably at its maximum temperature in February and the approach of autumn is not reflected in the surface temperatures until a month later in the year.

The surface charts show a common agreement: warm light water is seen near the coast of the South Shetland Islands and at the south-west end of the strait, with dense colder water close to Trinity Peninsula. Poorly saline water of comparatively high temperature, whose origin is the Bellingshausen Sea, is seen entering the strait between Low Island and Smith Island and continuing into the strait, causing warmer and less dense water at St. WS 390 on the line between Livingston Island and Trinity Peninsula. Another inflow of poorly saline warm water occurs between Smith and Snow Islands. On the line from King George Island to Trinity Peninsula the salinity of the surface water increases normally towards Trinity Peninsula as far as St. WS 384. At Sts. WS 385 and WS 386 an accumulation of water of considerably lowered salinity occurs in the surface layer. Thus a difference of 0·43 °/₀₀ is seen in the salinity observations between the surface and 30 m. at St. WS 386. From St. WS 386 to the coast of Trinity Peninsula the surface salinity then increases as usual. The accumulation of low salinity water in the upper layers at St. WS 385, and in particular at St. WS 386, is also reflected in the lower phosphate contents of the surface waters at these stations. It is remarkable because normally the surface salinity at these two stations would reflect the influence of the cold and more saline Weddell Sea water. No trace of the low salinity is found in the section from Livingston Island. The water in the surface layer at Sts. WS 385 and WS 386 is therefore surrounded by more saline water, and we think its occurrence can only be explained by the assumption that considerable ice melting must have recently occurred in this vicinity and that the diluted water had not yet been transported away. Consequently slack water conditions prevailed and layering occurred, leaving, in the absence of eddy motion and vertical mixing, a shallow discontinuity layer. A very strong north-east setting current was observed at St. WS 383 but was no longer present at St. WS 384. The topographical charts show that heavy water is present at St. WS 384 and that this station is on the right-hand side of the north-east flowing current at St. WS 383. An anti-clockwise eddy at St. WS 386 is shown in the topographic chart of the surface, and in these circumstances light water would be accumulated at this station. The whole temperature series at St. WS 386 is also remarkable, the many changes between relatively warm and cold water exhibited by the vertical observations are confusing. A similar occurrence, however, has been noticed by us before in the Bransfield Strait and is probably a direct consequence of a succession of ice freezings and meltings at this particular station whereby an abnormal temperature series was established.

The vertical sections of salinity, temperature and density (σ_t) of the section from King George Island to Trinity Peninsula are shown in Figs. 17–19. St. WS 385 was taken in a very strong north-east setting current which caused large stray on the water-bottle wires. Unprotected thermometers which give an indication of the true depth were unfortunately not fitted to the reversing water bottles used below 400 m. Consequently the isolines below this depth in the vertical sections at this station are situated too low.

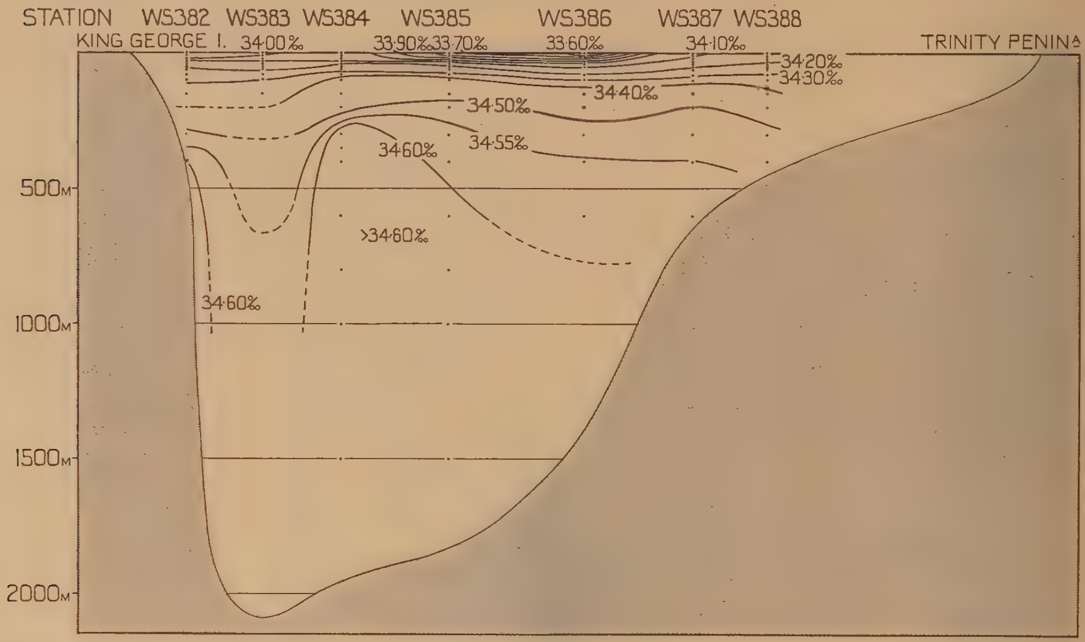

Fig. 17. Vertical section of salinity: King George Island to Trinity Peninsula, February 1929.

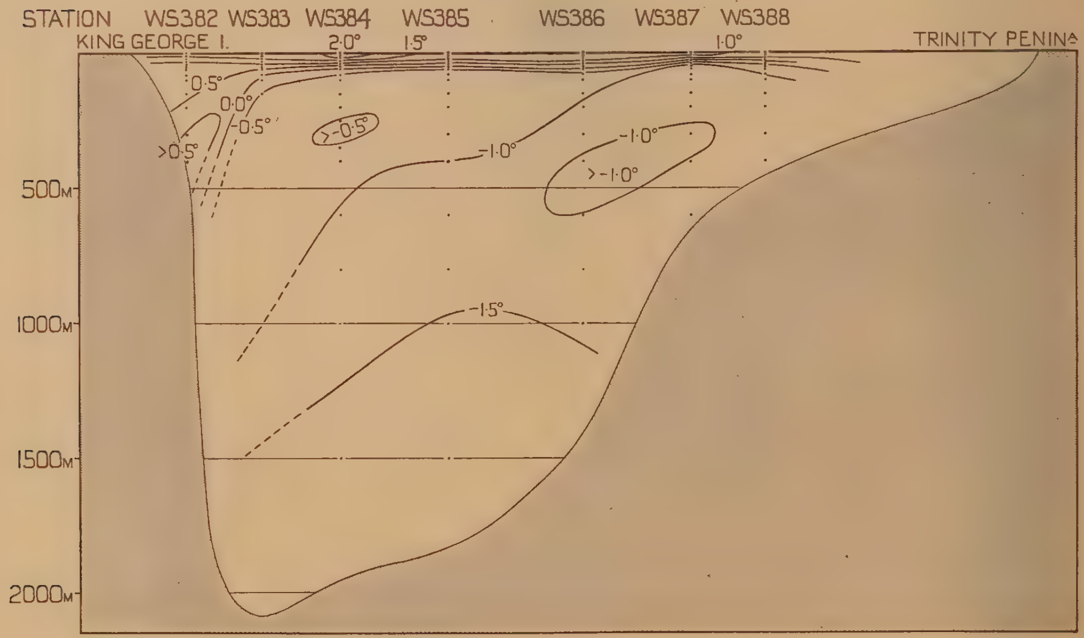

Fig. 18. Vertical section of temperature: King George Island to Trinity Peninsula, February 1929.

Nevertheless the slope of the lines of equal density between Sts. WS 382 and WS 383 shows the presence of the north-east going current which sets up the strait on this side.

In the topographical chart (Fig. 59) St. WS 384 is shown as occurring on the right-hand side of a strong current close to St. WS 383. In the southern hemisphere the lines of equal density in a vertical section will slope downwards to the left-hand side of the current direction provided the current decreases in velocity downwards from the surface. Consequently the lighter surface water will form a deeper layer on the left-hand of the current, whilst to the right, denser water will appear close to the surface. The vertical section of density distribution along this line of stations shows lighter water on either side of St. WS 384.

Accumulations of light water in the surface layers at Sts. WS 385 and WS 386 are seen in the vertical sections. Towards the coast of Trinity Peninsula the mean density for all depths increases. The influence of the warm deep water is very small and is restricted to a poor development at St. WS 382, except for rudimentary traces of intermediate maxima in temperature at some of the other stations in the section. St. WS 382 is the only station on this line at which Antarctic bottom water is absent. At all the other stations Antarctic bottom water is present at depths below 300–400 m. Owing to the very considerable vertical mixing which takes place in winter in the Bransfield Strait, the salinity of the Antarctic bottom water is at all times less inside the strait than in the surrounding seas outside.

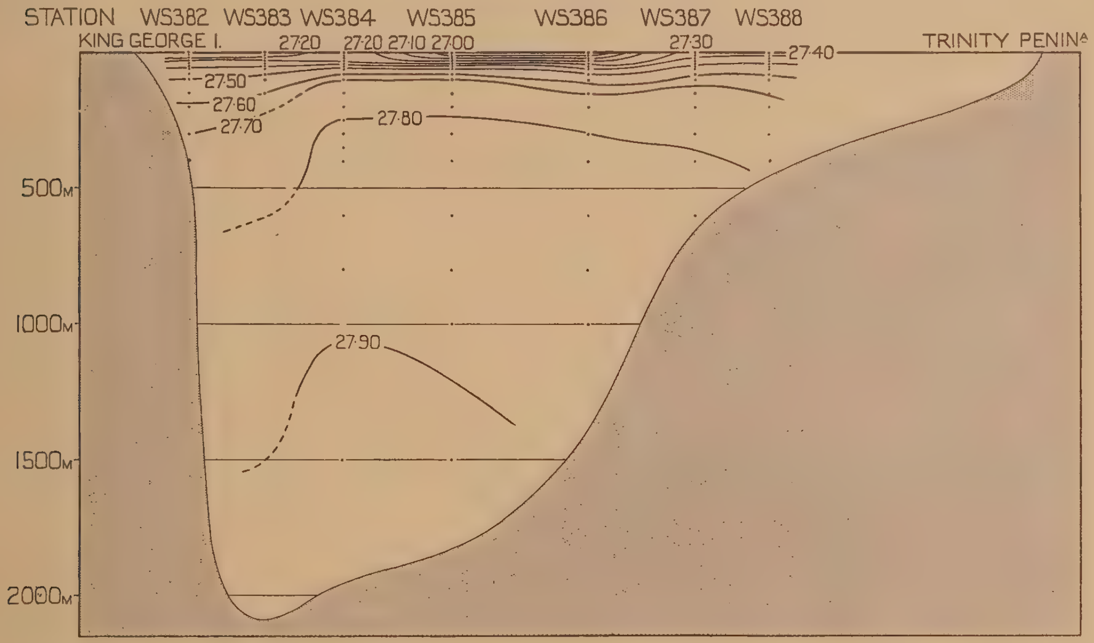

Fig. 19. Vertical section of density (σ_t): King George Island to Trinity Peninsula, February 1929.

In the section from Livingston Island to Trinity Peninsula, Figs. 20–22, similar conditions to those of the more north-easterly section appear, with the exception that the Weddell Sea influence is lessened. Also the warm deep water is much more apparent at the station nearest to Livingston Island, St. WS 393, than at the corresponding station, St. WS 382, in the north-east section, despite the fact that St. WS 393 is farther from the South Shetland Islands side of the strait than is St. WS 382. The influence of the colder water on the Trinity Peninsula side of the strait is seen as far as St. WS 392, and here no trace at all of the warm deep water is observable, the temperature falling continuously from surface to bottom. The difference in composition of the

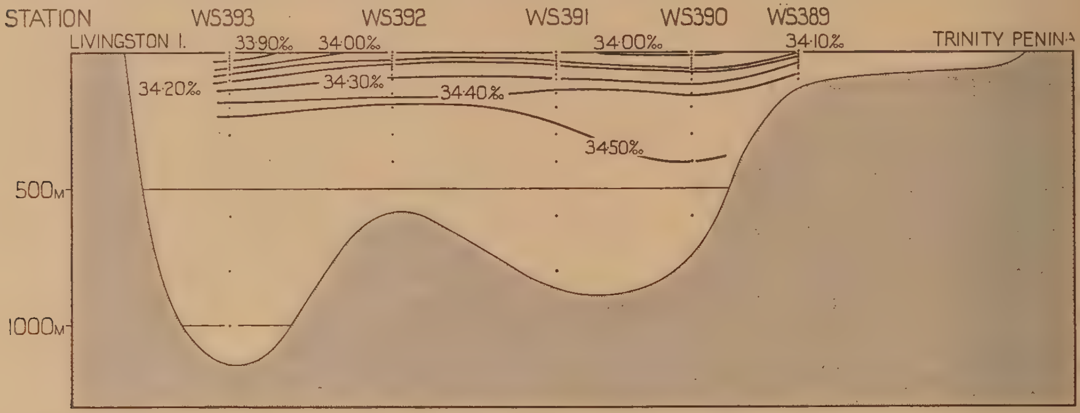

Fig. 20. Vertical section of salinity: Livingston Island to Trinity Peninsula, February 1929.

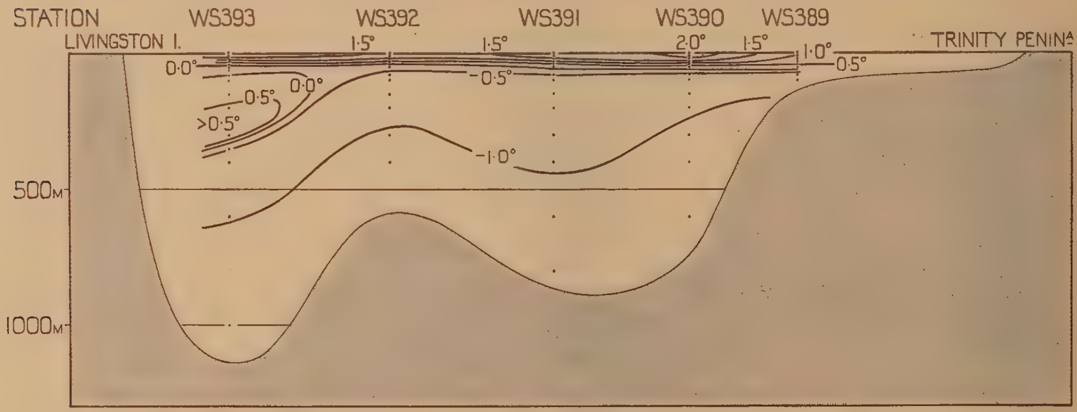

Fig. 21. Vertical section of temperature: Livingston Island to Trinity Peninsula, February 1929.

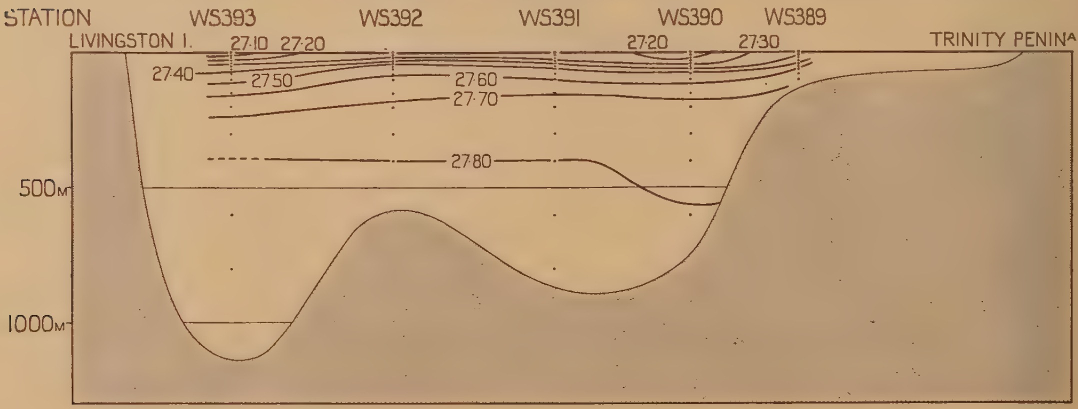

Fig. 22. Vertical section of density (σ_t): Livingston Island to Trinity Peninsula, February 1929.

water in the north-easterly current near the South Shetland Islands, and that in the remainder of the Bransfield Strait, influenced by the Weddell Sea and by the production in winter of Antarctic bottom water, is nowhere more clearly demonstrated than by a comparison of the temperature at 300 m. at Sts. WS 393 and WS 392. St. WS 393, situated in the north-easterly flowing current, has a temperature of 0·70° C. at 300 m., whereas St. WS 392 has a corresponding temperature of – 1·05° C. Thus a temperature difference of 1·75° C. is shown at 300 m. between two stations both inside the strait and approximately 12 miles apart. The temperature of 0·70° C. at 300 m. at St. WS 393 is due to the presence of warm deep water, and that of – 1·05° C. at 300 m. at St. WS 392 is due to mixed water containing a high proportion of Antarctic bottom water. The diagrams showing the relation between temperature and salinity for these two stations are shown in Fig. 23. The figures alongside the curves represent the depths in metres of the observations. The portion *BC* of the diagram for St. WS 393 represents the mass of mixed water occurring between the cold nucleus of the Antarctic surface water at 40 m. and the intermediate maximum temperature of the warm deep water at 300 m. The diagram for St. WS 392 shows that the mass of mixed Antarctic surface water and warm deep water is missing at this station.

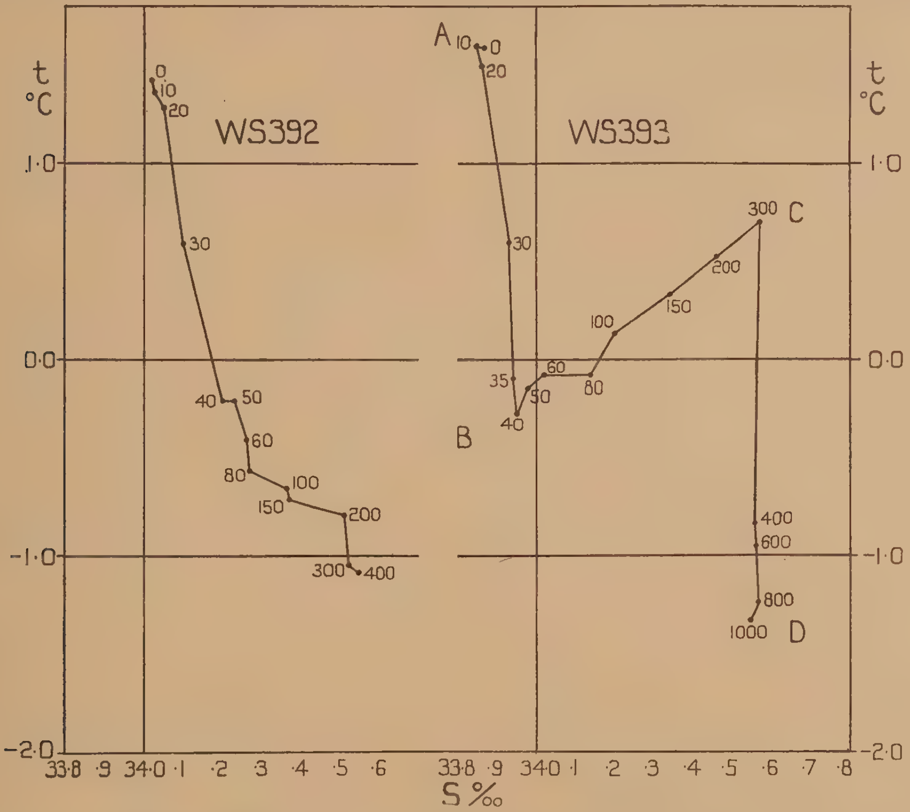

Fig. 23. Temperature-salinity diagram for Sts. WS 392 and WS 393.

At St. WS 390 an accumulation of slightly less saline but relatively warmer water in the 0–100 m. layer corresponds to an inflow of surface water from the south-west.

Figs. 24–26 show the vertical sections of salinity, temperature and density (σ_t) for the section between Brabant Island and Smith Island. The surface temperature and salinity of the stations in this section at the south-west end of the Bransfield Strait show that the surface layer is composed of warmer and considerably less saline water than in other parts of the strait. It has originated in the west and consists of part of the Antarctic surface water which flows out of the Bellingshausen Sea. The greater part of this stream passes north of the South Shetland Islands and flows north-east through the Drake Passage. Some, however, enters the Bransfield Strait between Low and

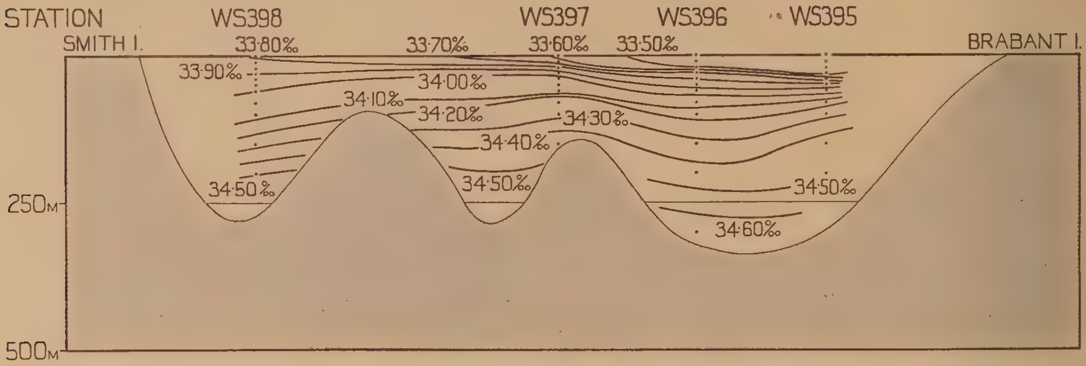

Fig. 24. Vertical section of salinity: Brabant Island to Smith Island, February 1929.

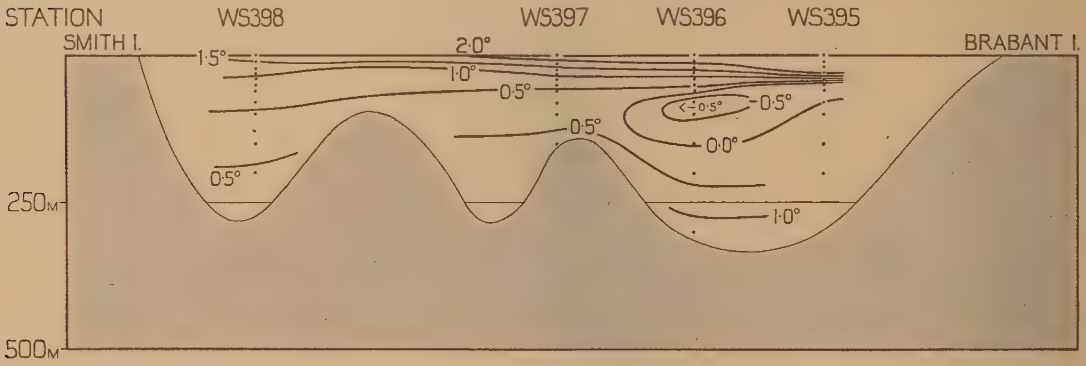

Fig. 25. Vertical section of temperature: Brabant Island to Smith Island, February 1929.

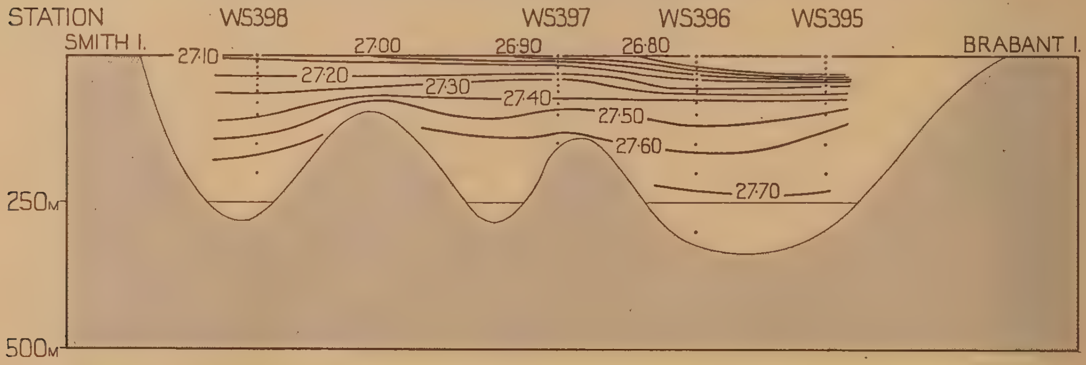

Fig. 26. Vertical section of density (σ_t): Brabant Island to Smith Island, February 1929.

Smith Islands and between Snow and Smith Islands. All trace of Weddell Sea influence is absent at this end of the strait. At all stations in this section the layer below the surface water consists of a mixture of Antarctic surface water with increasing amounts of warm deep water with depth. The shallow depth at these stations precludes the presence of Antarctic bottom water. Table II gives a comparison of the salinities and temperatures for the midway station of the three lines of stations taken in February 1929.

Table II

Depth in m.	North-eastern section St. WS 385		Middle section St. WS 391		South-western section St. WS 396	
	S ‰	*t*° C.	S ‰	*t*° C.	S ‰	*t*° C.
0	33·69	1·30	34·02	1·85	33·46	2·12
10	33·69	1·30	34·01	1·89	33·47	2·05
20	33·86	1·15	34·02	1·87	33·49	1·91
30	34·08	0·93	34·11	1·09	33·69	1·13
40	34·12	0·85	34·15	0·59	33·77	0·77
50	34·19	−0·05	34·18	0·17	33·85	0·56
60	34·25	−0·37	34·21	0·04	33·95	0·29
80	34·30	−0·64	34·25	−0·31	34·05	−0·83
100	34·43	−0·71	34·30	−0·85	34·13	−0·63
150	34·47	−0·81	34·42	−0·86	34·32	−0·01
200	34·52	−0·86	34·45	−0·98	34·43	0·32
300	34·59	−0·88	34·52	−0·96	34·66	1·18
400	34·59	−1·00	34·54	−0·99	—	—
600	34·61	−1·12	34·56	−1·07	—	—
800	34·62	−1·33	34·57	−1·13	—	—
1000	34·63	−1·52	—	—	—	—
1500	34·67	−1·63	—	—	—	—

The temperatures and salinities below 100 m. on the north-eastern and middle sections may be contrasted with those of the south-western section: at the midway station in the two former there is a complete absence of warm deep water, whereas in the latter, at St. WS 396, a temperature of 1·18° C. is recorded at 300 m.

An extra set of observations was made at St. WS 399, between Snow Island and Smith Island. This station is situated in the relatively deep channel between these islands and has a depth of 738 m. From the surface to a depth of 100 m. Antarctic surface water is present; below this depth it gradually mixes with the warm deep water, which occurs in considerable volume and has an intermediate thermal maximum at 400 m.

NOVEMBER 1929

In November 1929 the hydrological survey made in February of the same year by the R.R.S. 'William Scoresby' was repeated. As previously, horizontal sections of salinity, temperature and density (σ_t) have been drawn and are given in Figs. 27–9. Just as the surface temperatures and salinities in February 1929 reflected summer conditions, so the effect of late winter or early spring is seen in the surface values in November. The low salinity and relatively high temperature of the surface water in

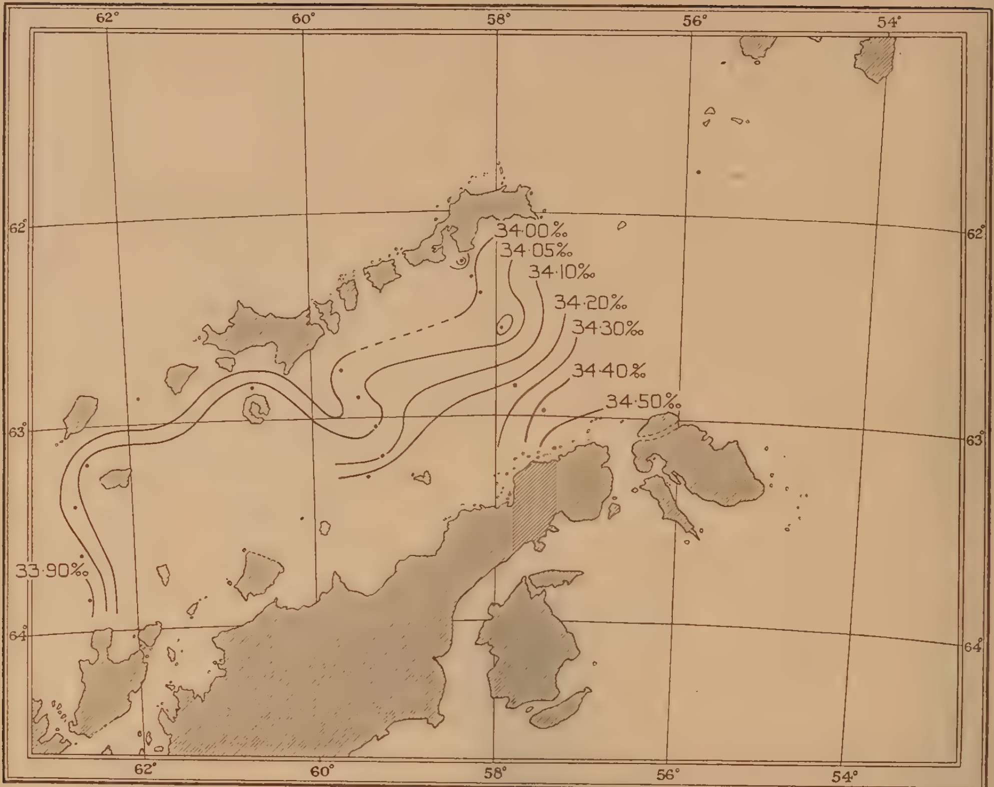

Fig. 27. Surface salinity: November 1929.

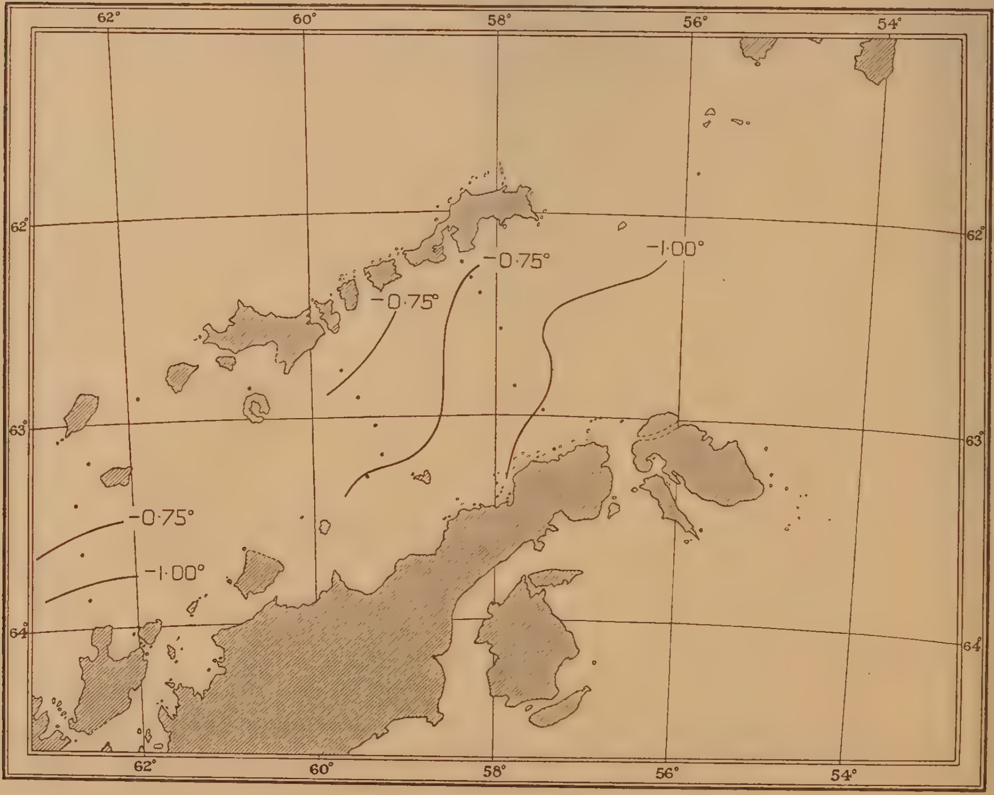

Fig. 28. Surface temperature: November 1929.

February have been replaced by a high salinity and low temperature in November. Thus on the King George Island to Trinity Peninsula line a difference of 0·29 °/₀₀ and 2·20° C. exists between February and November in the surface water at corresponding stations, WS 385 and WS 479, approximately 24 miles from Trinity Peninsula. In the horizontal sections the conditions at the surface show the same characteristics that prevailed in February when allowance is made for the increased salinity and decreased temperature due to the difference in season. Lighter water is found at the surface at the south-west end of the strait and at stations close to the South Shetland Islands, whereas towards Trinity Peninsula the surface salinity increases and reaches the high value of 34·51 °/₀₀ at the station nearest the peninsula. The surface temperature shows very little variation throughout the strait, the difference between the highest and lowest temperatures recorded amounting to only 0·53° C.

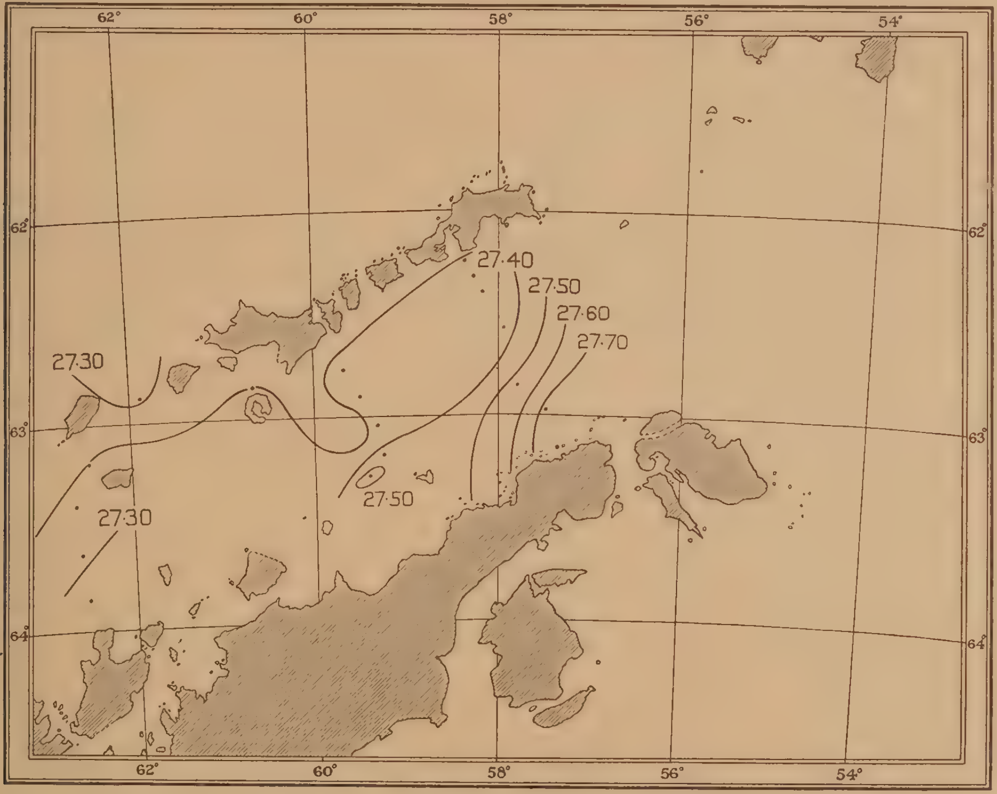

Fig. 29. Surface density (σ_t): November 1929.

The vertical sections from King George Island to Trinity Peninsula, Figs. 30–32, show a much greater development of the warm deep water at this end of the Bransfield Strait than in February. In February 1929 the only station on this line with a positive intermediate maximum temperature in this layer was St. WS 382, some 4 miles from King George Island, where a temperature of 0·53° C. was recorded at 400 m. The other stations on the same line in February recorded only traces of intermediate thermal maxima and all of negative temperature. In November, however, on this line, positive intermediate maxima are present at the following stations, Sts. WS 476, WS 477, WS 478, WS 479 and WS 480, covering a distance of approximately 42 miles from King George Island. At the next station, St. WS 481, the whole water column has been subjected to vertical mixing and from the surface to a depth of 400 m. the total variation in temperature and salinity amounts to only 0·10° C. and 0·06 °/₀₀ respectively. Thus in November the warm deep water was present almost as far as St. WS 481, where

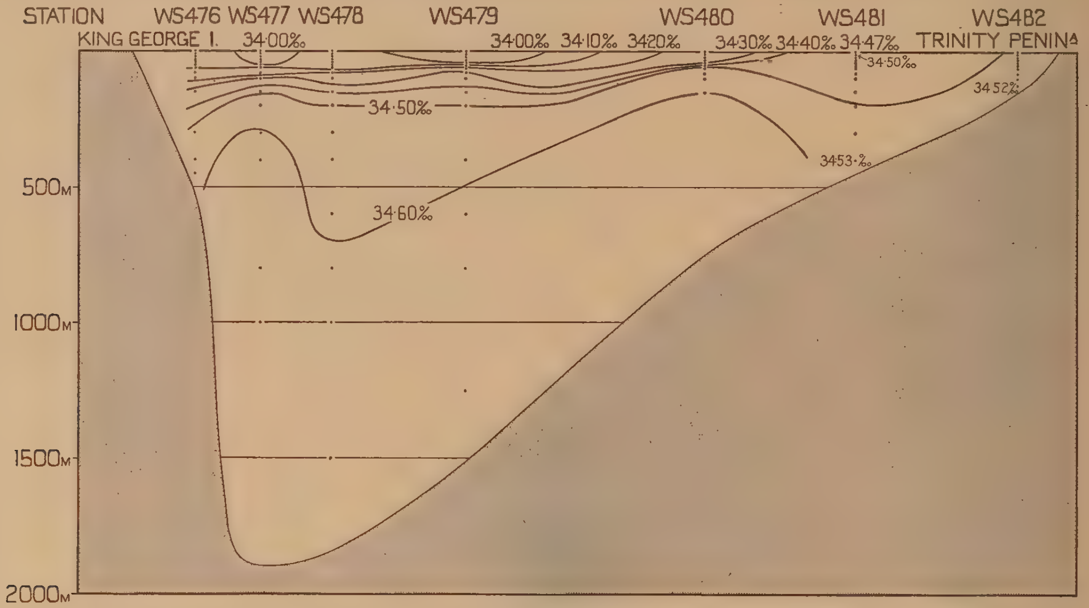

Fig. 30. Vertical section of salinity: King George Island to Trinity Peninsula, November 1929.

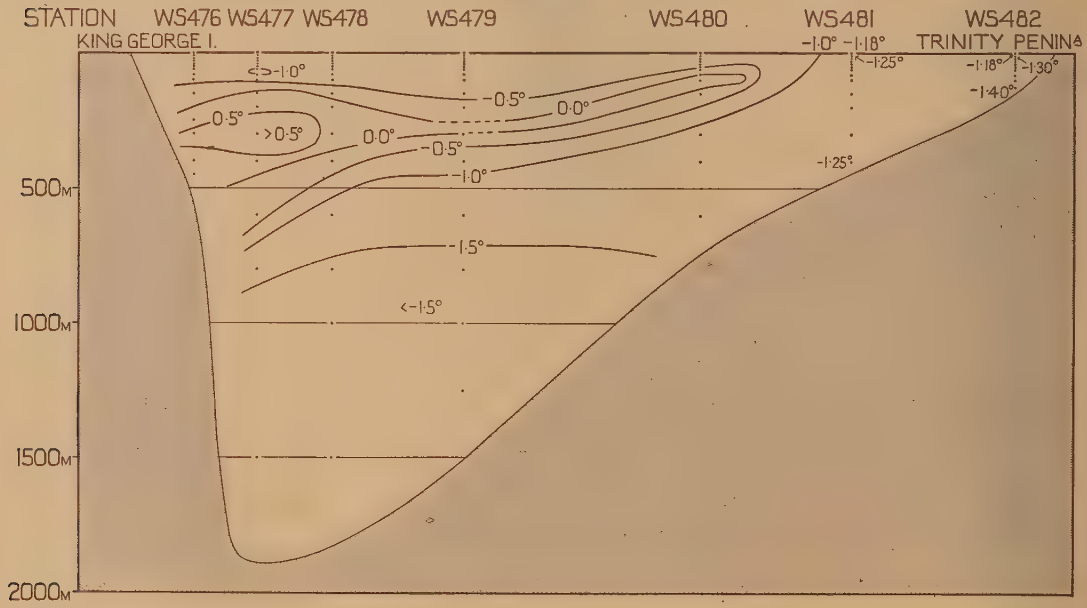

Fig. 31. Vertical section of temperature: King George Island to Trinity Peninsula, November 1929.

completely mixed and homogeneous water of Weddell Sea origin was present. In the vertical temperature section the warm deep water is seen to extend across the strait as an attenuated wedge-shaped layer, the apex of the wedge sloping up towards Trinity Peninsula.

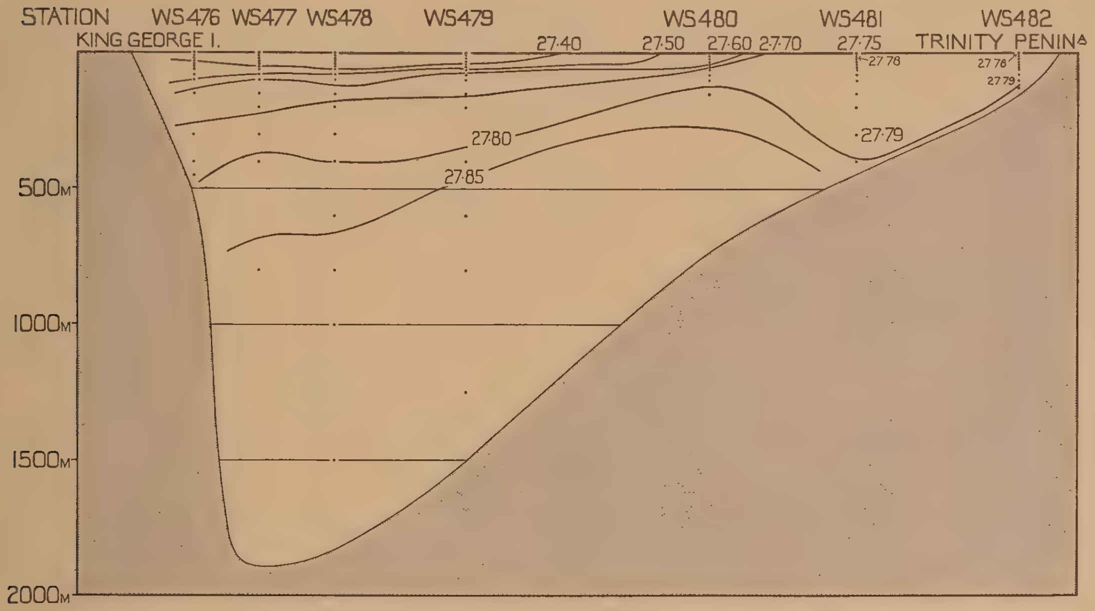

Fig. 32. Vertical section of density (σ_t): King George Island to Trinity Peninsula, November 1929.

The vertical sections of the line between Livingston Island and Trinity Peninsula are shown in Figs. 33–5. As with the section farther to the north-east the densest surface

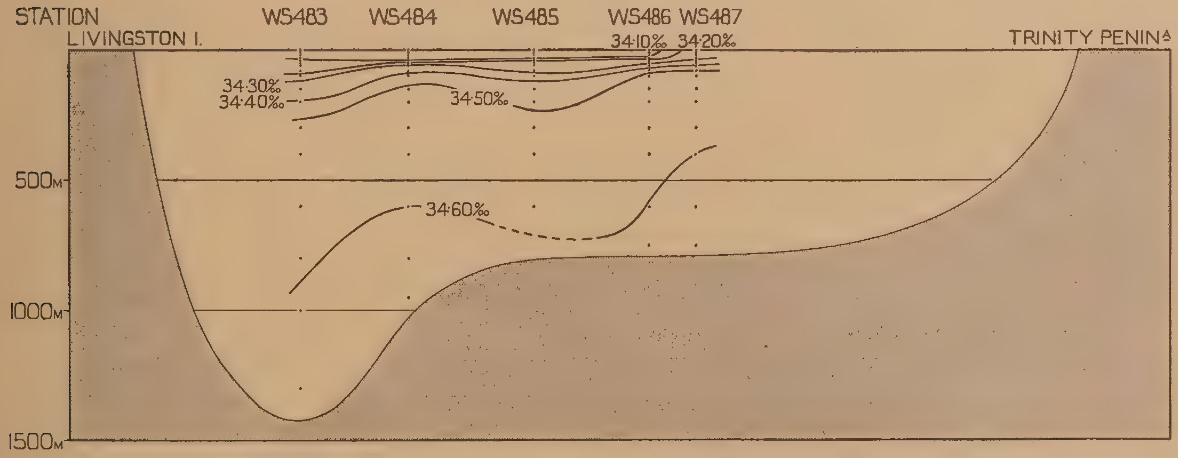

Fig. 33. Vertical section of salinity: Livingston Island to Trinity Peninsula, November 1929.

water is again found at the station closest to Trinity Peninsula, St. WS 487. The complete vertical mixing which was found at the corresponding station, St. WS 480, on the King George Island line is not seen at St. WS 487. The warm deep water has its maximum effect at St. WS 484, where an intermediate maximum temperature of 0·25° C. was found at 150 m. At the other stations in this section only rudimentary traces of intermediate maxima are found. The proportion of Antarctic bottom water in the depths below 150 m., besides increasing normally with depth, also increases towards the coast of Trinity Peninsula.

The vertical sections of the stations at the south-west end of the strait are shown in Figs. 36–8. The surface temperature at St. WS 488, close to Brabant Island, is but slightly higher than that at the east end of the strait close to Trinity Peninsula. The surface salinity at the other stations of the section from Smith Island to Brabant Island is very similar to that of the rest of the strait, except at the stations close to Trinity Peninsula which show the influence of dense Weddell Sea water. Dilution by melting ice in the spring has not yet taken place farther to the south-west in sufficient amount to cause surface salinities of less than 33·80 °/$_{oo}$ to appear at this end of the strait, and moreover this minimum value is only found at St. WS 488 close to Brabant Island. At all

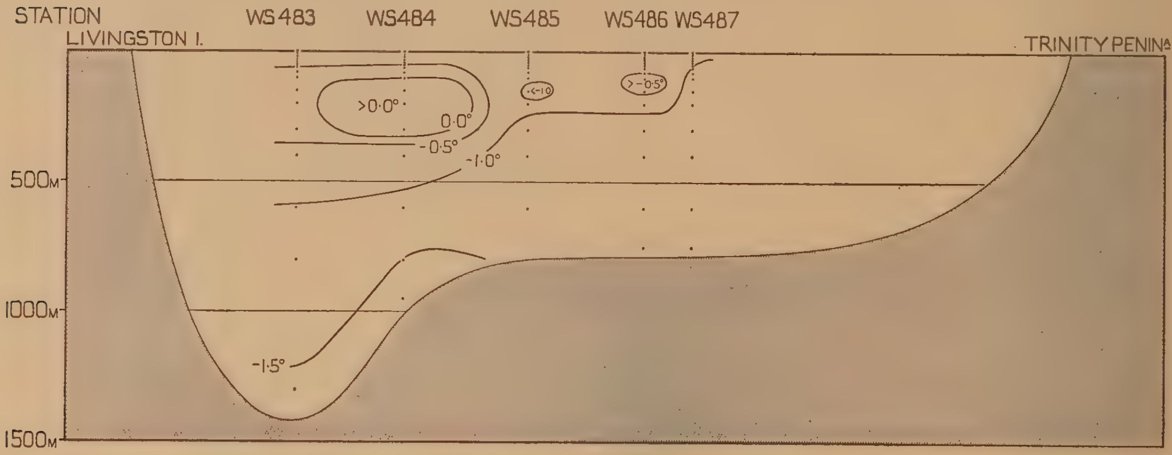

Fig. 34. Vertical section of temperature: Livingston Island to Trinity Peninsula, November 1929.

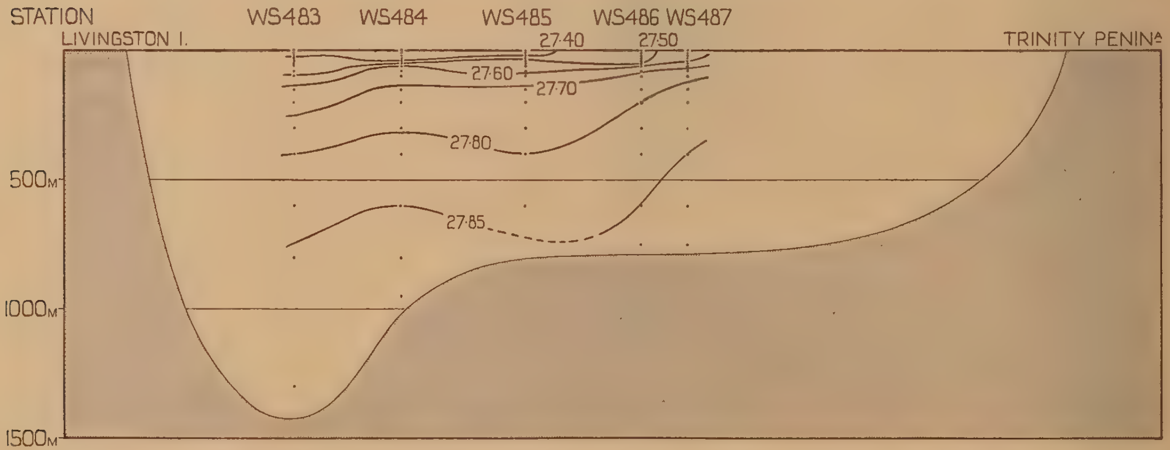

Fig. 35. Vertical section of density (σ_t): Livingston Island to Trinity Peninsula, November 1929.

stations in this section the layer between the Antarctic surface water and the sea-bottom consists of warm deep water, there being no Antarctic bottom water present.

As in February a station, St. WS 492, was taken between Snow Island and Smith Island. At this station the water below 200 m. consisted of warm deep water. It is probable that most of the warm deep water which exists in the Bransfield Strait enters the strait in the channel 600–700 m. deep between Snow and Smith Islands and flows south of Deception Island, possibly through a gap in the supposed ridge between

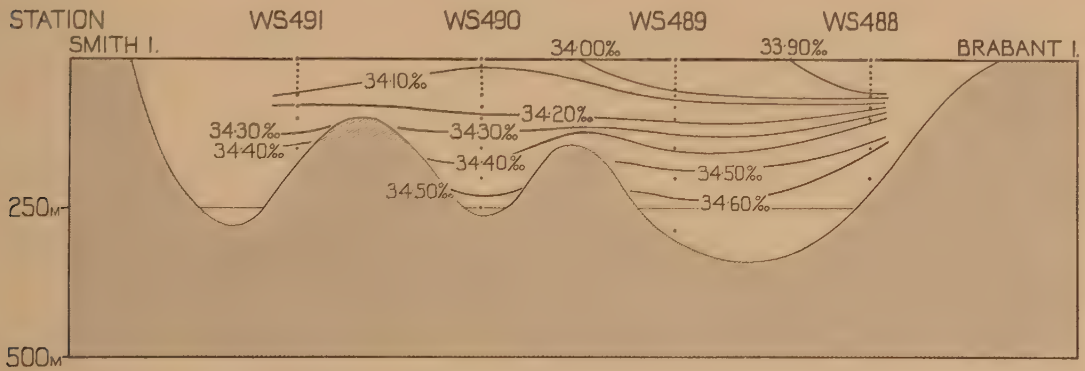

Fig. 36. Vertical section of salinity: Brabant Island to Smith Island, November 1929.

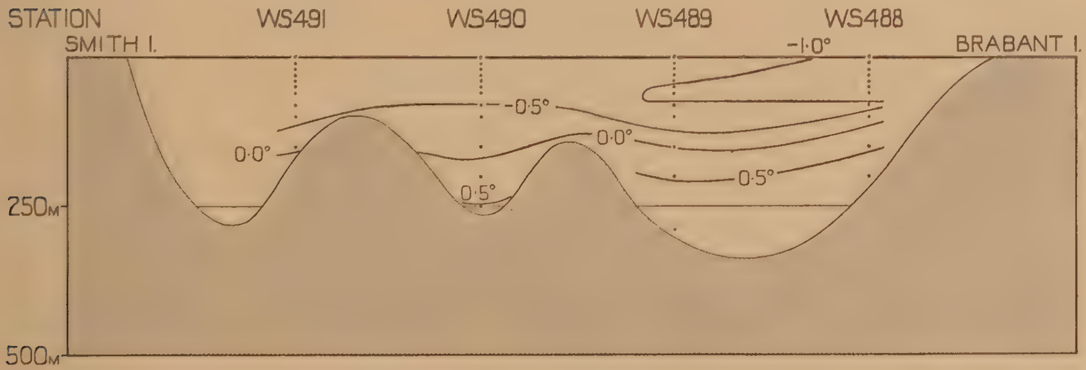

Fig. 37. Vertical section of temperature: Brabant Island to Smith Island, November 1929.

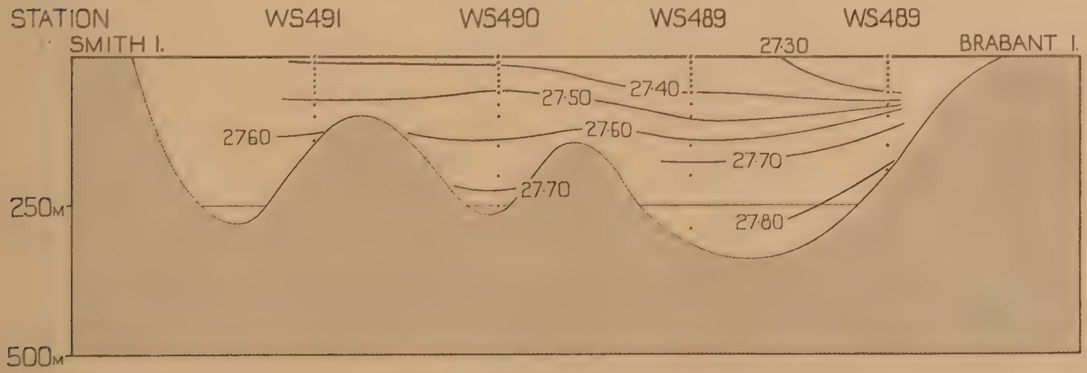

Fig. 38. Vertical section of density (σ_t): Brabant Island to Trinity Island, November 1929.

Deception and Trinity Islands. Thus the two deep basins of the Bransfield Strait may be connected by a flow of warm deep water. Further soundings on the line between Deception Island and Trinity Island are urgently needed.

DECEMBER 1930

In late December 1930 a line of stations was attempted by the R.R.S. 'Discovery II' from midway between Elephant and Clarence Islands to Joinville Island. Unfortunately after St. 541 heavy pack-ice, which stretched as far as could be seen, prevented any further stations being made in this direction. A new line of stations was then made between Cape Melville and Trinity Peninsula and another between Snow Island and Trinity Island. Temperature observations and samples of salinity and phosphate content were taken at all stations, with samples for oxygen content determination at alternate stations. Horizontal sections are given for temperature, salinity and density in Figs. 39–41. The three lines of stations are rather too far apart to show the surface movements in any detail. In general the surface salinity and density increase in all three sections towards Trinity Peninsula, and as usual the surface water at the north-east end of the strait is colder than that at the south-west. Compared with the observations made by the R.R.S. 'William Scoresby' in November of the previous year, the surface in December is composed of warmer but more dense water. This is explained

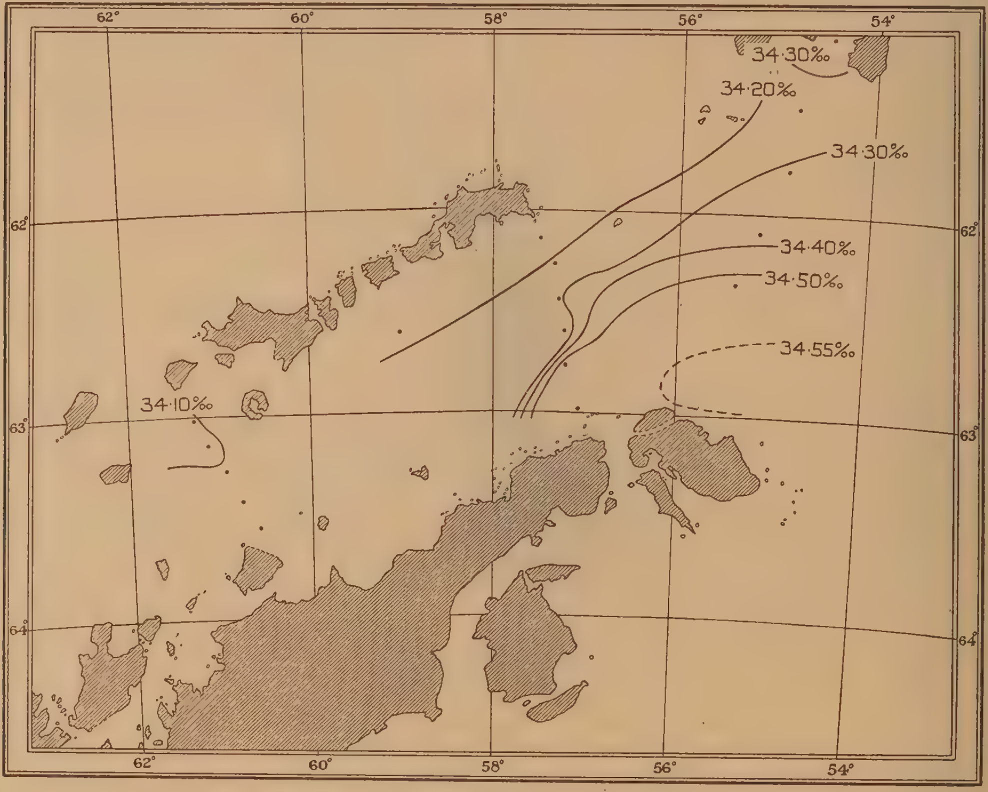

Fig. 39. Surface salinity: December 1930.

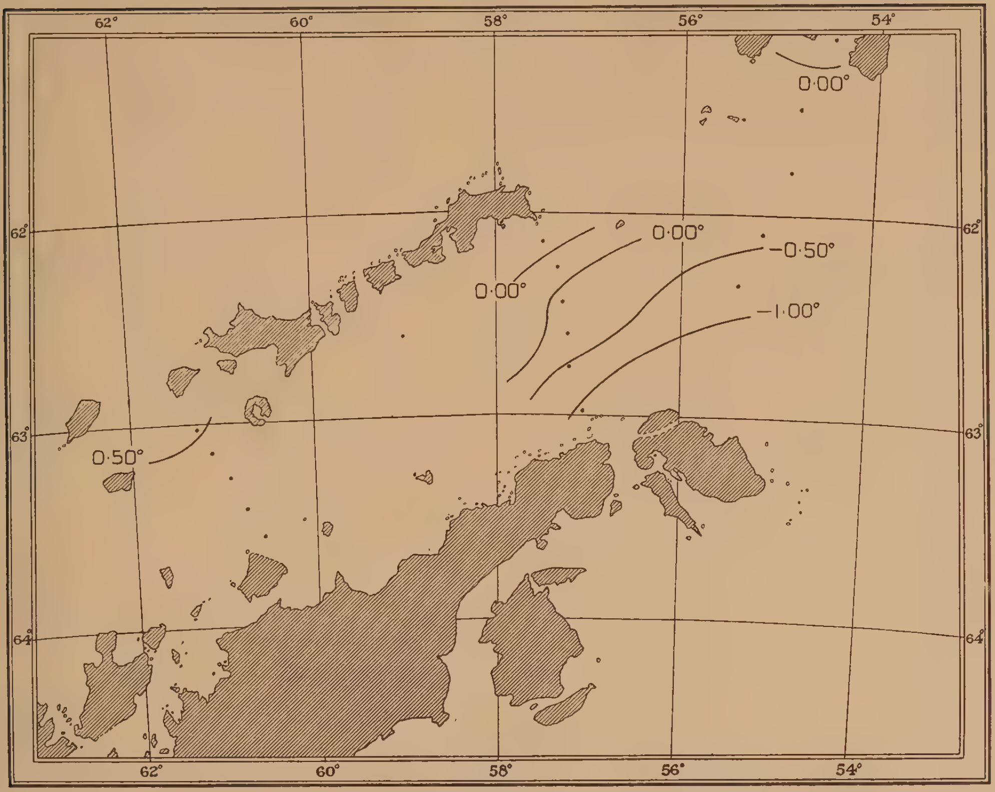

Fig. 40. Surface temperature: December 1930.

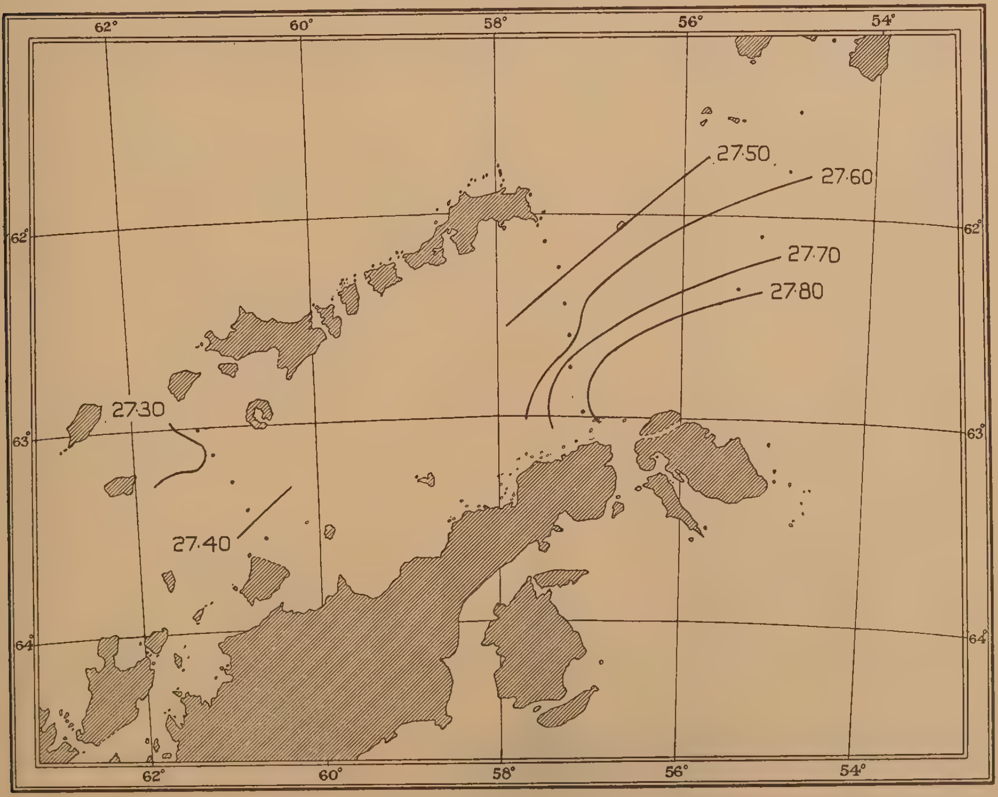

Fig. 41. Surface density (σ_t): December 1930.

by the fact that the 1930 observations were closer to summer conditions by over a month. The increased surface salinity is probably due to the presence of much more

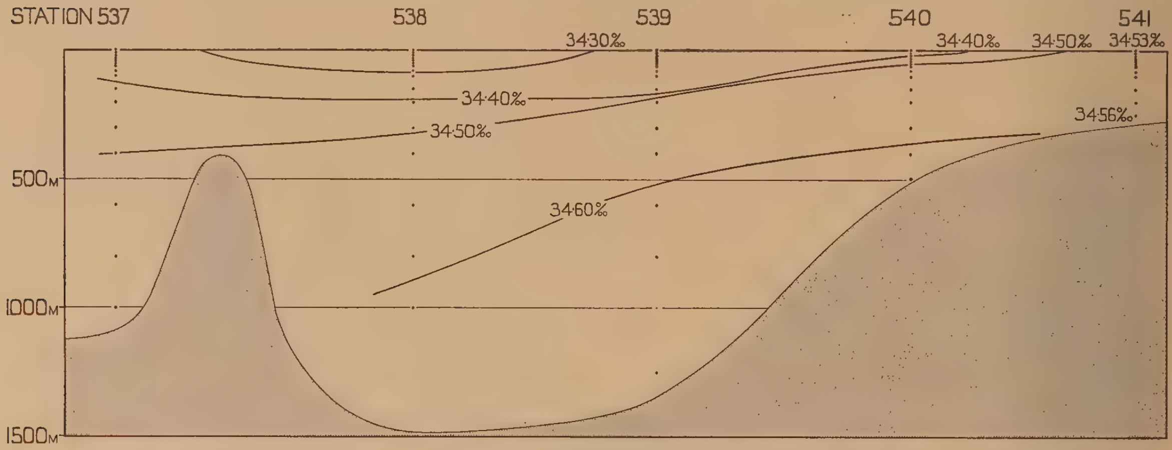

Fig. 42. Vertical section of salinity: Elephant Island towards Joinville Island, December 1930.

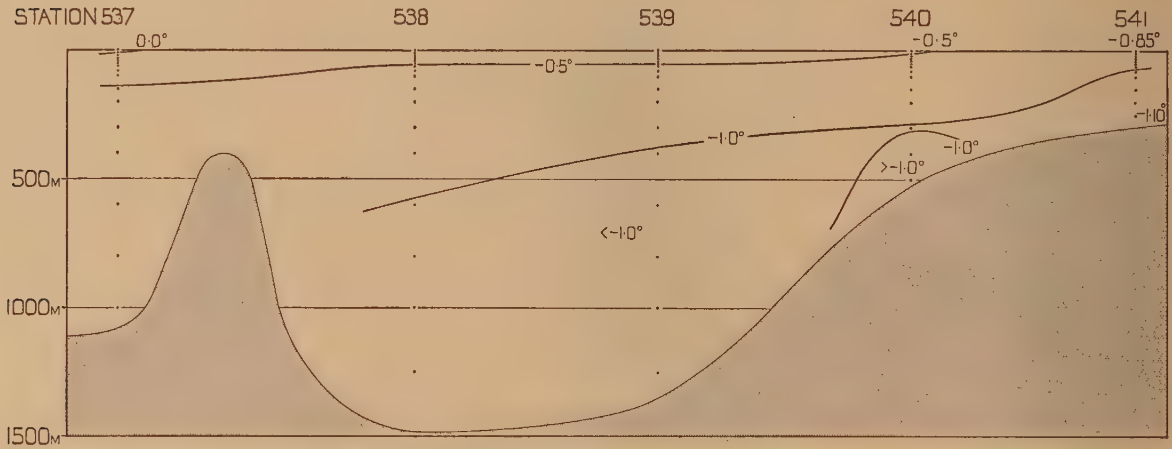

Fig. 43. Vertical section of temperature: Elephant Island towards Joinville Island, December 1930.

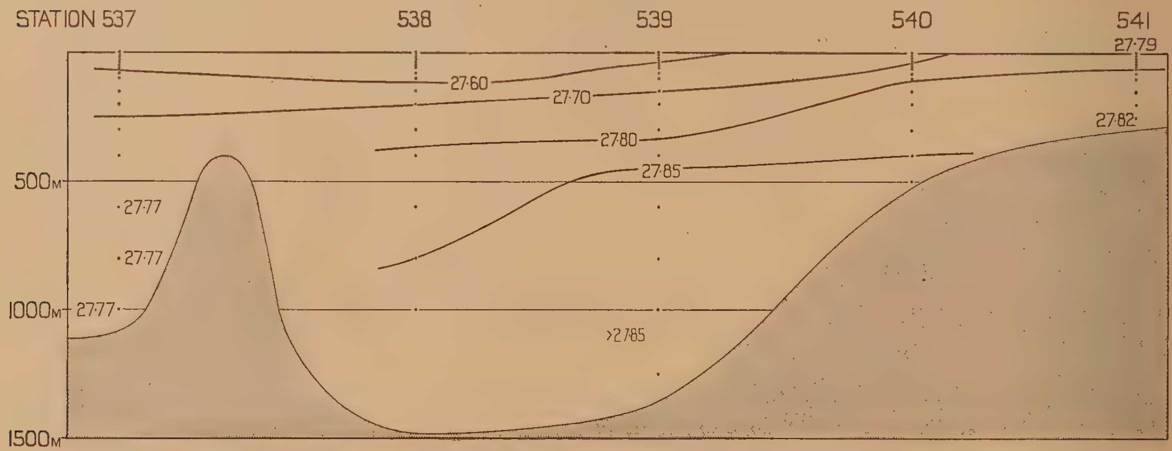

Fig 44. Vertical section of density (σ_t): Elephant Island towards Joinville Island, December 1930.

pack-ice in this area in the spring of 1930 than in November 1929. Thus in December 1930 the open water was left more saline before subsequent dilution by ice melting occurred. The vertical sections, Figs. 42–4, on the line from between Elephant and Clarence Islands towards Joinville Island, show the isolines sloping up towards St. 541, the nearest station to Joinville Island that could be worked. St. 541 is situated on the broad continental shelf north-east of Joinville Island, and the water here, throughout the whole vertical column, has been completely mixed and consists of Antarctic surface water of Weddell Sea origin. In this section the presence of warm deep water in traces is indicated by the slight inversions of temperature which occur at all stations on this line except in the completely mixed water at St. 541. Sts. 538 and 540 show two temperature inversions at different depths; the intermediate maximum temperature at the greater depth of St. 540 occurs at a depth of 500 m., which is within 10 m. of the sea-bottom. Thus at this station the bottom water itself contains an admixture of warm deep water. The increase in salinity with depth and the presence of temperature inversions show a stable layering at all stations in this line, except at St. 541 where the whole column is practically homohaline.

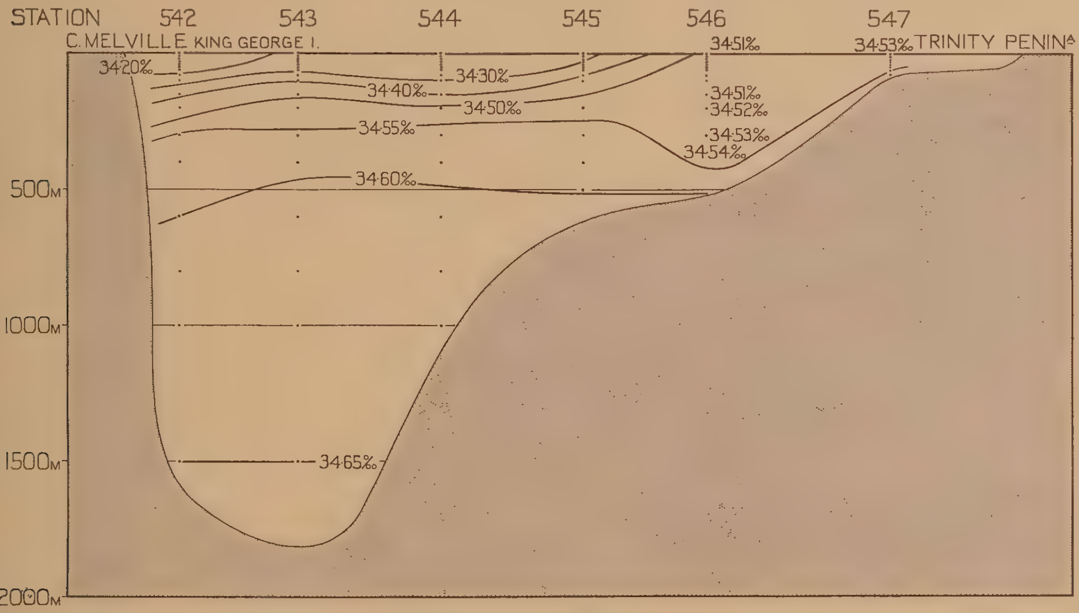

Fig. 45. Vertical section of salinity: C. Melville, King George Island, to Trinity Peninsula, December 1930.

The vertical sections of the line from Cape Melville to Trinity Peninsula, Figs. 45–7, show as usual the increase of salinity and decrease of temperature in the surface water as the line progresses towards the coast of Trinity Peninsula, except at St. 543, some 15 miles from Cape Melville. At this station the current is flowing more to the north, and positive temperatures are found in the first 30 m. The greatest increase in surface salinity occurs between Sts. 545 and 546. At the latter station the 0–400 m. layer is practically homohaline, whilst the uppermost portion of the layer has been warmed by insolation. At St. 547 the whole vertical column, consisting of Antarctic surface water, is nearly homothermal and homohaline. At the other stations on the line more stable conditions are observed and both warm deep water and Antarctic bottom water are present. The warm deep water has its greatest influence at St. 542, where an intermediate maximum temperature of 0·00° C. is found at 300 m. No thermal evidence of

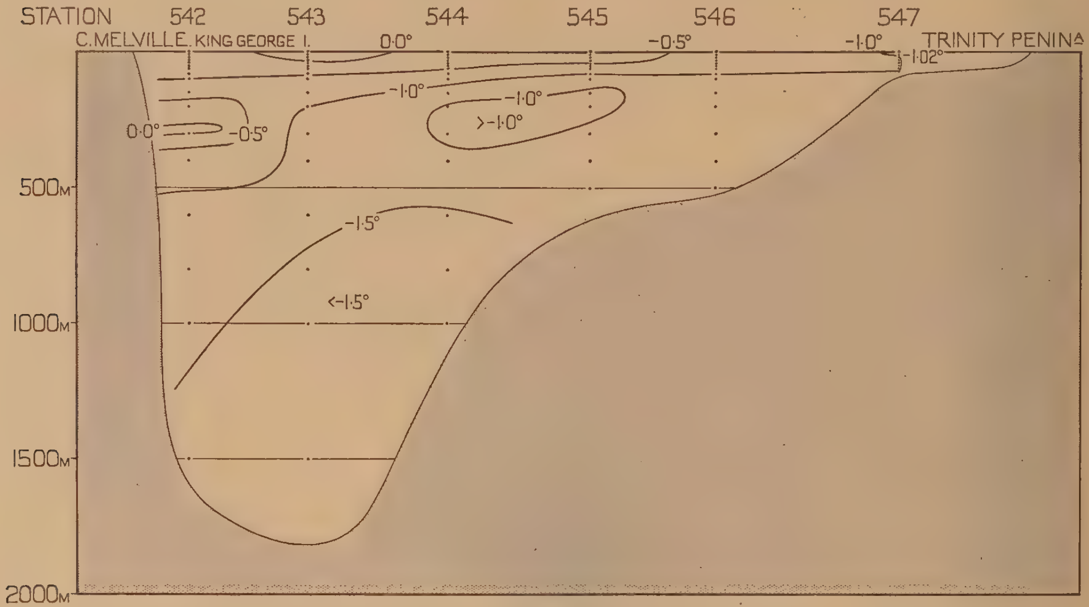

Fig. 46. Vertical section of temperature: C. Melville, King George Island, to Trinity Peninsula, December 1930.

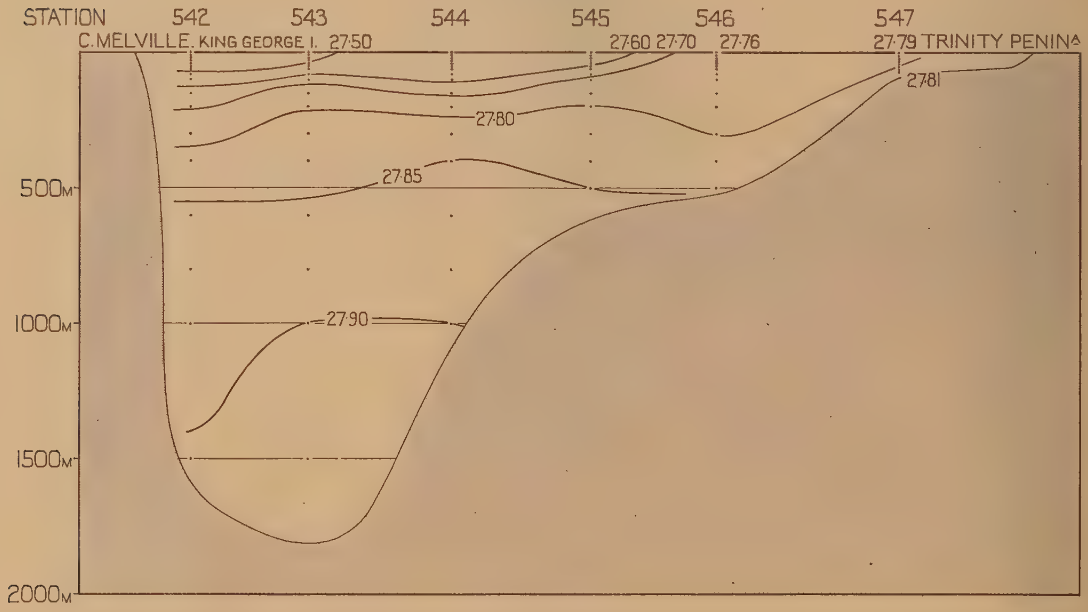

Fig. 47. Vertical section of density (σ_t): C. Melville, King George Island, to Trinity Peninsula, December 1930.

this layer was observed at the next station, but at Sts. 544 and 545 small temperature inversions below the surface layer indicate the influence of the warmer water. At St. 545 a second though small temperature inversion is seen at 500 m., or some 100 m. above the sea-bottom. This corresponds to a temperature inversion, also at 500 m., which occurs below the vertically mixed surface layer at St. 546. The presence of such an irregular temperature series at Sts. 538, 540, 545 and 546 and the proximity of these stations to the flow of pack-ice from the Weddell Sea, would seem to indicate that the level of the upper boundary of the warm deep water may be depressed during a season when vertical mixing is particularly easy, i.e. when the surface is freezing or being cooled by pack-ice. This would account for the depth of the lower temperature inversion. Subsequently new relatively warm water may appear at a higher level and form the upper inversion. An alternative explanation may be that warm deep water from the Weddell Sea flows over the ridge between Elephant and Clarence Islands to Joinville Island, and thus at these stations warm deep water from both the west and the east is present.

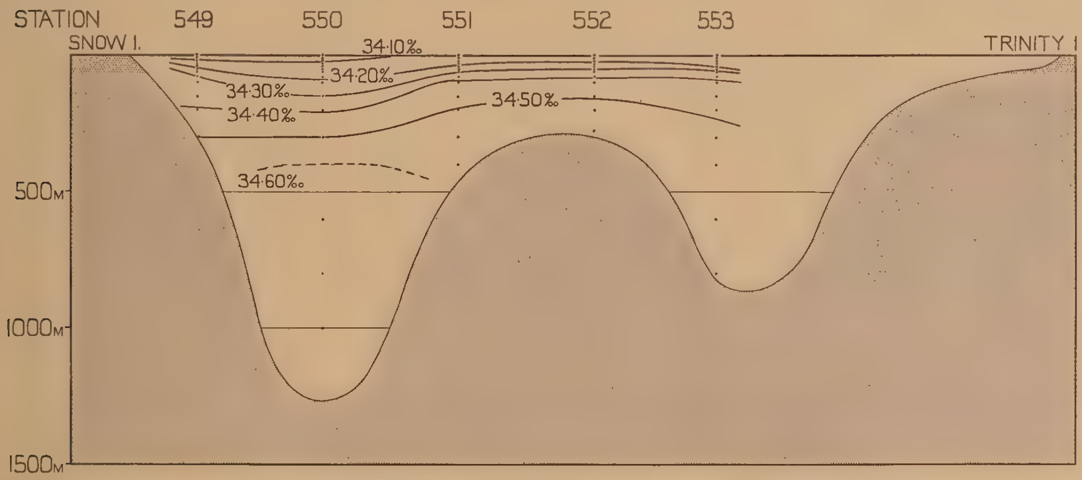

Fig. 48. Vertical section of salinity: Snow Island to Trinity Island, December 1930.

Antarctic bottom water is found in considerable quantity at depths below the intermediate temperature maxima.

The vertical sections of the line between Snow Island and Trinity Island are given in Figs. 48–50. The line cuts across the smaller basin at the south-west end of the Bransfield Strait. The surface water at all the stations has been warmed by the sun. A cold nucleus of the Antarctic surface water, with temperature below – 0·50° C., is seen in the two most northern stations and at the station nearest Trinity Island. The depth of the minimum temperature increases southwards from Snow Island. In general the surface salinity increases towards Trinity Island. Near Snow Island, below the depth of the cold nucleus of the surface layer, the temperature increases and reaches the relatively high value of 0·50° C. in the warm deep water at 400 m. at St. 550. The rise in the sea-bottom at Sts. 551 and 552 apparently prevents any appreciable amount of warm deep water from appearing at further stations in the section, as the intermediate temperature maxima at stations other than St. 550 are very faint. Probably the greatest part of the warm deep water inside the strait at the south-west end flows eastwards past St. 550, south of Deception Island, through a gap in the supposed ridge between Deception and Trinity Islands. Below the level of the intermediate temperature maxima at Sts. 550 and 553 the water contains increasing proportions of Antarctic bottom water with depth.

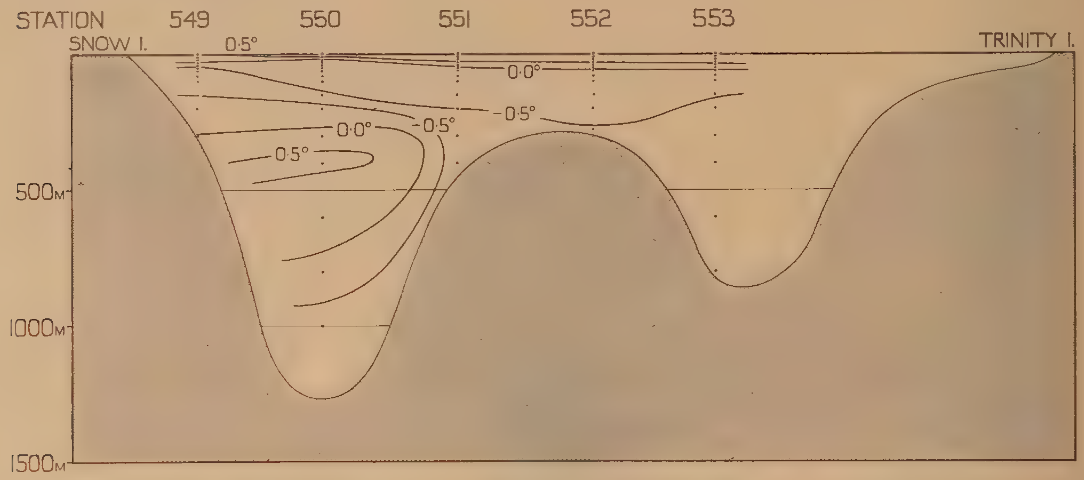

Fig. 49. Vertical section of temperature: Snow Island to Trinity Island, December 1930.

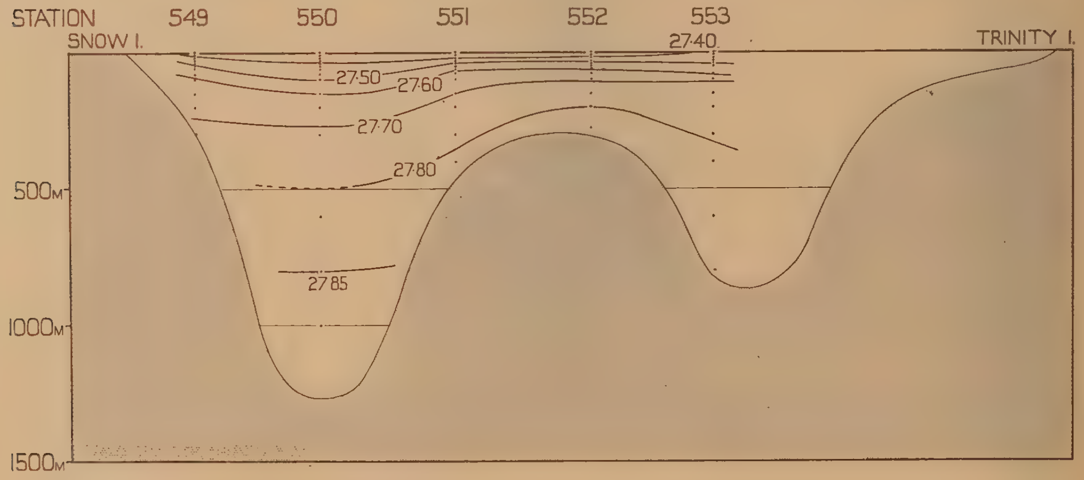

Fig. 50. Vertical section of density (σ_t): Snow Island to Trinity Island, December 1930.

WATER MOVEMENTS

The treatment by dynamical methods of the data obtained from the various surveys of the Bransfield area has been a difficult task. As may be seen from the bathymetric chart, very great differences of depth occur at adjacent stations and it is impossible from the present data to obtain sufficient figures from which satisfactory topographical charts may be drawn of the sea surface in relation (say) to the 2000 or 1500 decibar surfaces. Consequently some arbitrary treatment is necessary on account of the great differences in depth at the stations. In future work in the Bransfield Strait and similar areas the number of stations must be greatly increased, particularly on the steeply shelving continental slopes leading to the main channel through the strait.

If two stations are considered whose depths differ greatly, it cannot be assumed that along the potential surface cutting the bottom at the station of lesser depth the difference of pressure is nil. That is to say the physical characteristics of the water between the stations at depths below that of the shallower station affect the height or topography of the various isobaric surfaces at all points between the stations. Consequently, when determining the difference of height in the sea surface or any other isobaric surface, a method must be employed in which the specific volume of the sea water below the potential surface referred to above is taken into account. Such a method was worked out by Jacobsen and Jensen (1926). These workers, however, assumed a linear variation in the specific volume in both a horizontal and a vertical direction. A glance at the vertical section of density in the Bransfield Strait shows that this is not always correct. When the difference of depth between the stations is great the correction factor *C* in the Jacobsen and Jensen formula generally becomes great and may be dubious. However, by using this method the main currents in the Bransfield Strait were determined as follows. Water from the Bellingshausen Sea flows in a north-easterly direction at the south-western end of the strait, is diverted by the shelves of the islands of Brabant, Low and Smith, and enters the Bransfield Strait between Smith and Low Islands. Another inflow is in the relatively deep channel between Smith and Snow Islands. This water continues up the strait in a north-easterly direction, after having passed north or south of Deception Island. The north-easterly current along the southern coast of the South Shetland Islands is relatively strong. Part of the water which has passed Deception Island makes a characteristic bend to the south-east and sometimes reaches more than half-way across the strait before it turns again to the north-west to join the current along the South Shetland Islands. At the eastern end of the strait the influence of a current from the Weddell Sea is apparent. Having thus obtained a general idea of the water movements, it was decided to try and find a more exact method for determining the topography of the various surfaces required.

Professor B. Helland-Hansen, Director of the Geophysical Institute at Bergen, kindly gave me particulars of a method which he and Nansen had previously worked out. A vertical section of the anomaly of specific volume is constructed. At depths greater than 1500 or 2000 m. in an area such as the Bransfield Strait it is seen that the isosteres are horizontal. In this case it may be assumed that the isobaric and isosteric surfaces lie parallel to the level surfaces, and hence there are no acting forces and no convection currents. The depth at which the isosteres become horizontal is then taken as the datum level of zero current for all stations in the section. The isostere at this datum level is then extended horizontally on either side to cut the bottom contour and continue along the line of stations. Above the datum level the isosteres are usually inclined; they are continued until they cut the bottom contour, and from this point the lines are drawn horizontal. In this way a series of levels and values is obtained which allows the computation of the dynamic heights of the sea surface and other isobaric surfaces at shallow stations relatively to those at deep stations. Prior to the construction of the vertical section of specific volume anomaly, the curves of the distribution of temperature, salinity and density with depth were drawn. In a few cases the values of temperature and salinity were smoothed when this was necessary, and this was done in such a manner that the interpolated values of temperature and salinity were in good agreement with the density and specific volume anomaly curves. The dynamic depths of the various isobaric surfaces are calculated in the usual manner, adding to the known values of the specific volume those which have been artificially obtained in the manner described above. Fig. 51 illustrates the method for obtaining the extra values of specific volume anomaly.

From the dynamic calculations one station could be selected at which the level of the surface of the sea was lowest, i.e. the most dense water occurred at this station. By taking the dynamic depths above the datum level it was then possible to obtain relative heights of the sea surface at the various stations and find the difference between the other stations and the station selected. Occasionally a datum station was chosen which was not that of the most dense water. When the height of the sea surface above the datum isostere at a station was lower than that of the datum station, this was expressed as a minus difference of level in dynamic centimetres.

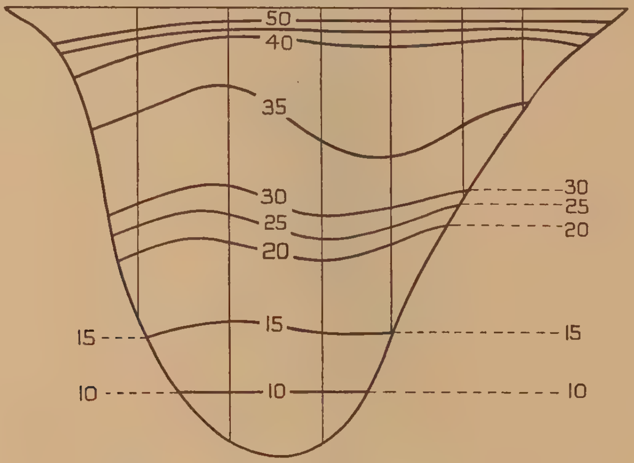

Fig. 51. Sketch showing method of extrapolation used in obtaining specific volume anomalies.

The two principal lines of stations in the Bransfield Strait were from King George Island and from Livingston Island to Trinity Peninsula. By use of the Helland-Hansen and Nansen method the relative height of the sea surface at stations along each line was found. It was then necessary to find a connection between the two lines in order to be able to construct dynamic charts. This has been done by combining a station from one line with a station from the other, either by the Jacobsen and Jensen method, if the two stations in the link were selected so that the difference in depth of the stations was small, or by a direct comparison in the case of the deepest stations where the values of the specific volume anomalies were the same at the lowest depths. Table III gives the stations in the two principal lines which were linked by means of the Jacobsen and Jensen method.

Table III

Date	Stations	Difference in depth of stations in m.
April 1927	205–200	110
February 1929	WS 387–WS 390	109
November 1929	WS 480–WS 486	47

In the observations made in December 1930, two of the lines of stations were from Cape Melville, King George Island, to Trinity Peninsula and from midway between Elephant and Clarence Islands in the direction of Joinville Island.

NOVEMBER 1929 AND DECEMBER 1930

After a preliminary survey of the data it was decided to commence with the November 1929 observations and try to build up a composite picture of the lines of flow in the strait by adding to the November charts the values in December 1930. This representation is open to criticism because of the fact that observations from two different years are brought together. It is, however, impossible to give a picture of the flow, either into or out of the strait, of Bellingshausen Sea water and of the influence of the water from the Weddell Sea, unless stations on either side of the two principal lines of November 1929 are considered. The presence of Weddell Sea water at the north-east end of the strait and its influence across the strait had been previously suspected, but it was not until the values of December 1930 had been added to those of the November 1929 survey that the turn of this water to the north across the strait was demonstrated. Table IV and the explanation below show how the relative heights of the sea surface at stations in November 1929 were calculated.

By using the Jacobsen and Jensen formula

$$C = \frac{z}{2}(Vb_2 - Va_2),$$

where C = correction to be added to the difference of the depths of the isobaric surface at the depth of the shallower station; z = the difference in depth in metres of the two stations; Vb_2 and Va_2 = specific volumes *in situ* at the two stations at a depth equal to that of the shallower station; we obtain

$$\text{WS 480–WS 486} = -2{\cdot}03 \text{ dynamic cm.} \qquad \ldots\ldots(1).$$

By a direct comparison of the dynamic depth of the 1800 decibar surface we have

$$\text{WS 480–WS 482} = 0{\cdot}05 \text{ dynamic cm.} \qquad \ldots\ldots(2).$$

Subtracting (1) and (2) we obtain WS 482–WS 486 = – 2·08.

Assuming WS 482 to be the basic station we obtain WS 482 = 0·00 and WS 486 = 2·08.

These values have been used to obtain the relative heights of the sea surface at the stations of the November survey, and have been entered in column 4 of Table IV.

Table IV

(1) Station	(2) Dynamic depth to 1800 decibar surface in dynamic m.	(3) Height in dynamic cm. above St. WS 482	(4)	(5) Relative height in dynamic cm. above St. WS 480
WS 476	1744·0561	11·11	11·11	11·06
WS 477	1744·0263	8·13	8·13	8·08
WS 478	1744·0192	7·42	7·42	7·37
WS 479	1743·9923	4·73	4·73	4·68
WS 480	1743·9455	0·05	0·05	0·00
WS 481	1743·9534	0·84	0·84	0·79
WS 482	1743·9450	0·00	0·00	– 0·05
	Dynamic depth to 1300 decibar surface in dynamic m.	Height in dynamic cm. above St. WS 487		
WS 483	1261·0522	8·07	8·00	7·95
WS 484	1261·0129	4·14	4·07	4·02
WS 485	1261·0230	5·15	5·08	5·03
WS 486	1260·9930	2·15	2·08	2·03
WS 487	1260·9715	0·00	– 0·07	– 0·12

Now St. WS 482 is a very shallow station, the bottom depth being 152 m., and in the preparation of a series of topographic charts it is better to choose as a basic station one whose depth is at least equal to the greatest depth represented in a chart of dynamic topography. Since all the values in column 4 are purely relative, any station may be arbitrarily chosen as the basic station, and in column 5 of the above table St. WS 480 has been thus selected and the values at the other stations correspondingly altered.

The lines of stations in December 1930 from Cape Melville to Trinity Peninsula and from between Elephant and Clarence Islands in the direction of Joinville Island were linked by direct comparison of the dynamic depths to the 2000 decibar surface. In this case St. 543 was chosen as the basic station, and Table V contains the heights of the sea surface of the other stations relative to this station.

It has been previously mentioned that the results from November 1929 would if possible be linked with those of December 1930, so as to obtain a more complete picture of the water movements. By inspection of the vertical sections of the anomaly of specific volume for the two lines from King George Island in these two years, it was assumed that at 2000 m. the specific volume anomaly in each case was 10×10^{-5} and that no current existed at this depth in either year. Then, by a direct comparison of the dynamic depth to the 2000 decibar surface for St. WS 478 in November 1929 and St. 543 in December 1930, we have the following relation for the difference of level in dynamic cm. of the sea surface at these two stations:

WS 478–St. 543 = 7·25 dynamic cm.

Then, if we allow the relative heights for November 1929 to remain, we can use the value WS 478 = 7·37, which was obtained in Table IV, column 5, in the above relation between St. WS 478 and St. 543. Thus we obtain St. 543 = 0·12 relative to the November 1929 values. As we have already obtained relative values for December 1930 (Table V) this new value (St. 543 = 0·12) can be substituted in these values, so that in Table VI we have a direct comparison between November 1929 and December 1930.

Table V

Station	Height in dynamic cm. above surface of sea at St. 543
538	7·17
539	3·60
540	0·14
541	− 0·57
542	5·59
543	0·00
544	− 0·10
545	− 1·27
546	− 2·57
547	− 4·64

It only remains to link the line of stations from Snow Island to Trinity Island taken in December 1930 with the line of November 1929 from Livingston Island to Trinity Peninsula. This was done by a direct comparison of the dynamic depths to the 1300 decibar surface of Sts. 550 and WS 483 as follows:

St. 550–WS 483 = 3·53 dynamic cm.;

but in Table IV, column 5, we have WS 483–WS 480 = 7·95 dynamic cm. By addition, therefore, St. 550–WS 480 = 11·48 dynamic cm. Thus we have now a complete relative relationship for the level of the sea surface for the majority of the stations in November 1929 and December 1930 above that at St. WS 480. These figures are given in Table VI below.

The values in Table VI were entered on a chart of the area and dynamic isobaths were drawn at intervals of every dynamic centimetre. In the construction of the isobaths attention was paid to the law of Ekman which states the change of direction of flow of a convection or gradient current when approaching shallowing or deepening water. In the southern hemisphere a gradient current will turn to the left on approaching a shallower part of the ocean and to the right when approaching deeper water. Topographical charts for surfaces other than that of the sea surface were made on the basis of the above table by using the differences of dynamic depth to these surfaces of the various stations and the basic station WS 480. In this way topographic charts for the levels of 0, 50, 100, 200, 300, 400 and 600 m. were constructed and are given in Figs. 52–8. On account of the fact that observations from two different years have been used in these charts, it is not strictly accurate to represent the dynamic isobaths as continuous lines. Consequently the junction of the November and the December results is shown by a definite break in the lines on these charts, indicating the uncertainty in the combination of the results from two years. Arrows have been added to the dynamic isobaths to indicate the direction of the currents.

In the topographic chart of the sea surface the same current features are shown as were previously mentioned, but the great influence of water from the Weddell Sea is especially emphasized. When the line of stations from Elephant and Clarence Islands was being taken, it was impossible to make observations as far as Joinville Island because very heavy pack-ice was met just beyond St. 541. This pack-ice must have come from the Weddell Sea, and its present position was the resultant of wind and current direction. The combined observations from November 1929 and December 1930 show a current of Weddell Sea water setting to the west between Sts. WS 481 and WS 480, which turned back close to the latter station and flowed to the north, joining the current along King George Island from the south-west. On the present evidence it is difficult to estimate how much of the current close to Cape Melville flows counter-clockwise round the South Shetland Islands, and how much flows north of Bridgeman Island and then to the east. Between Sts. 538 and 541 a current towards the east is shown, but the dynamic isobaths to the north of St. 539 have not been joined up with the corresponding lines close to King George Island because it is impossible at present to estimate the direction of flow of water across the probable ridge between Elephant and King George Islands. There is no doubt of the anti-clockwise circulation around the islands of the South Shetland group. The observations at St. 537 between Elephant and Clarence Islands have not been included in these charts because this station is situated in a relatively deep basin between these islands and is shut off to the south by a ridge which prevents free circulation with the water to the north-east of the Bransfield Strait.

Table VI. *Relative heights in dynamic centimetres of the level of the sea surface above that at St. WS* 480

November 1929		December 1930	
St. WS 476	11·06	St. 538	7·29
WS 477	8·08	539	3·72
WS 478	7·37	540	0·26
WS 479	4·68	541	− 0·45
WS 480	0·00	542	5·71
WS 481	0·79	543	0·12
WS 482	− 0·05	544	0·02
WS 483	7·95	545	− 1·15
WS 484	4·02	546	− 2·45
WS 485	5·03	547	− 4·52
WS 486	2·03	549	10·09
WS 487	− 0·12	550	11·48
		551	5·91
		552	4·42
		553	5·46

The northerly set of the current between Joinville and King George Islands explains

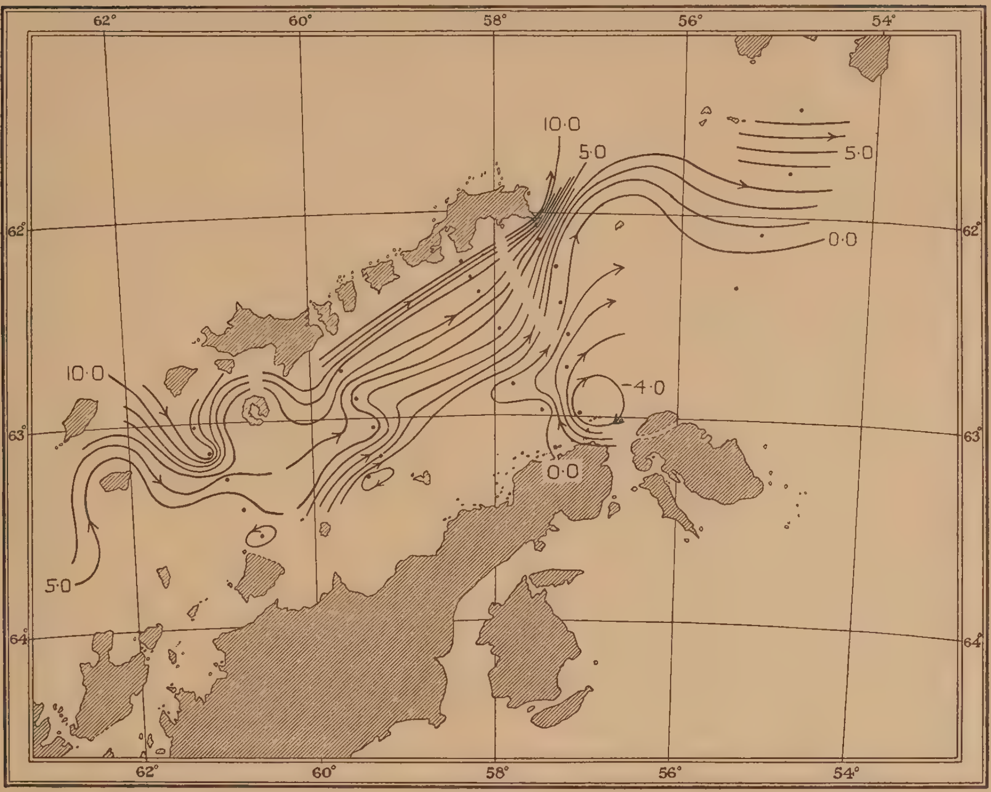

Fig. 52. Relative topography of the sea surface: November 1929 and December 1930.

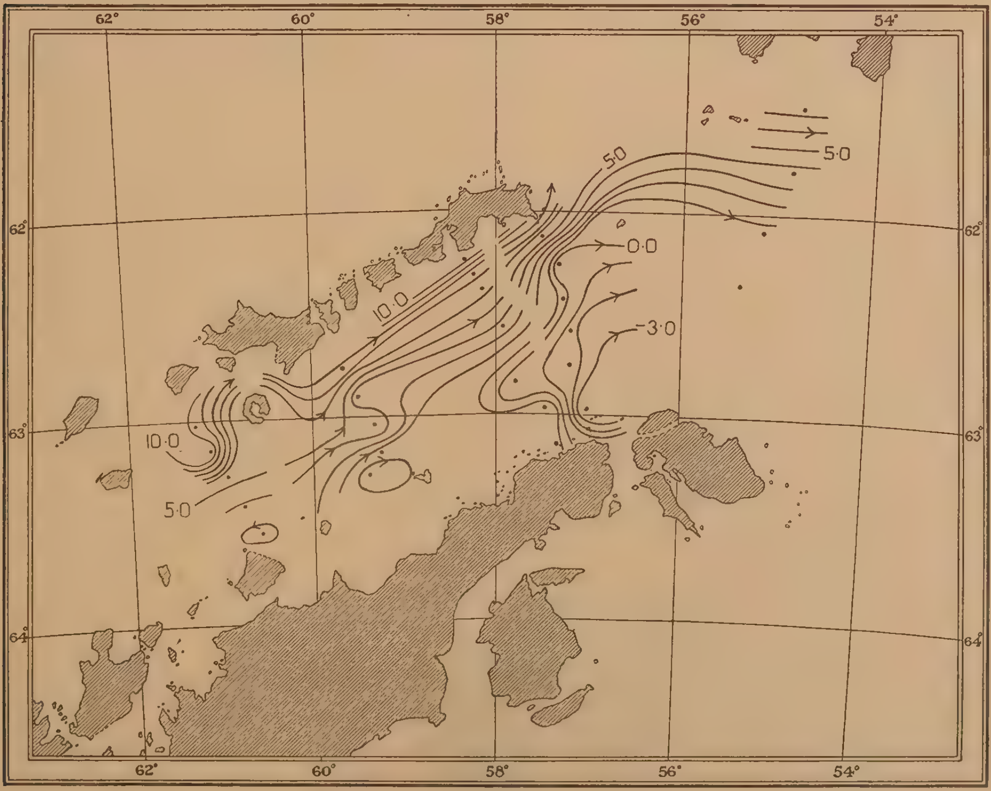

Fig. 53. Relative topography: 50 m., November 1929 and December 1930.

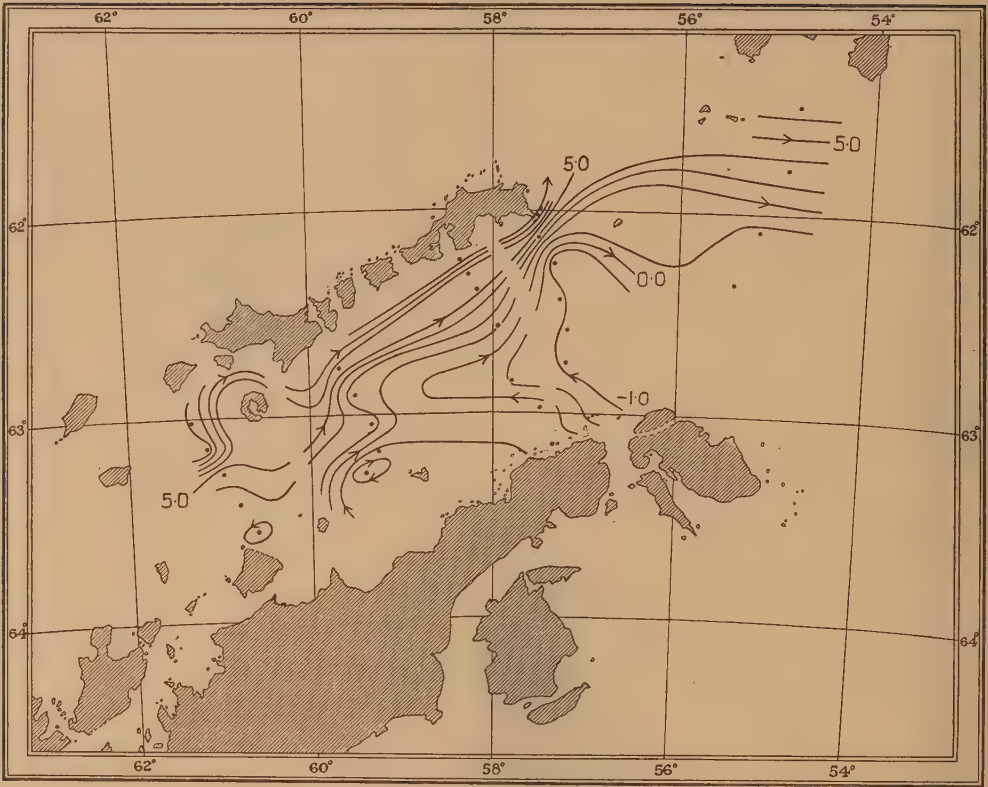

Fig. 54. Relative topography: 100 m., November 1929 and December 1930.

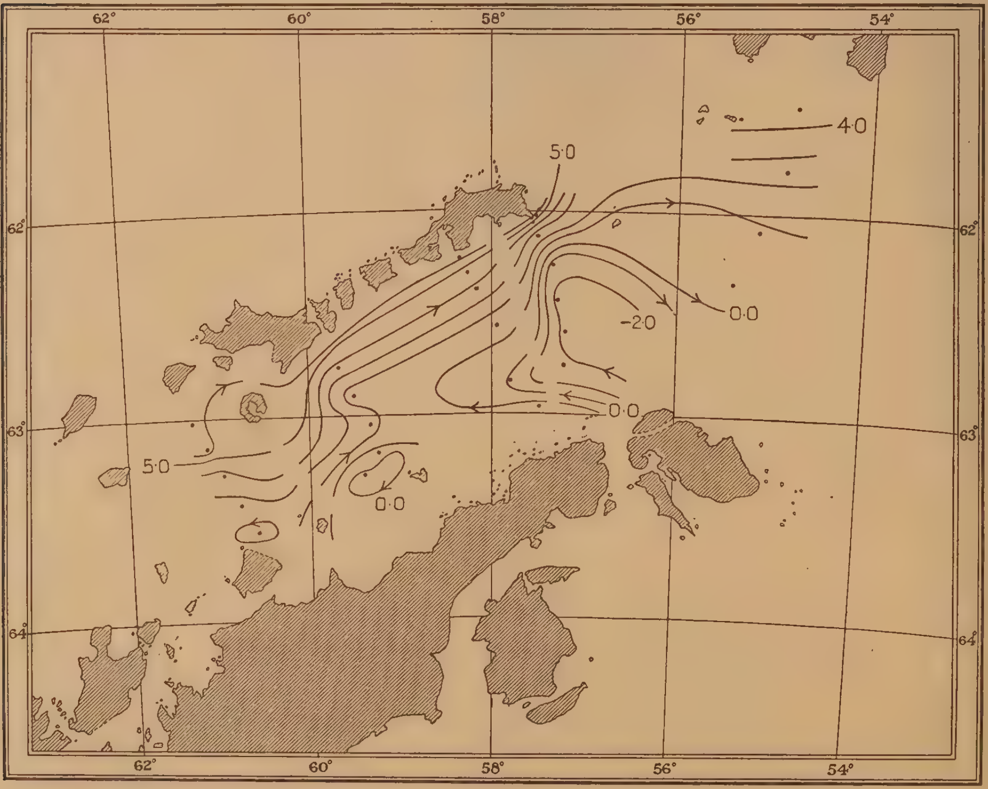

Fig. 55. Relative topography: 200 m., November 1929 and December 1930.

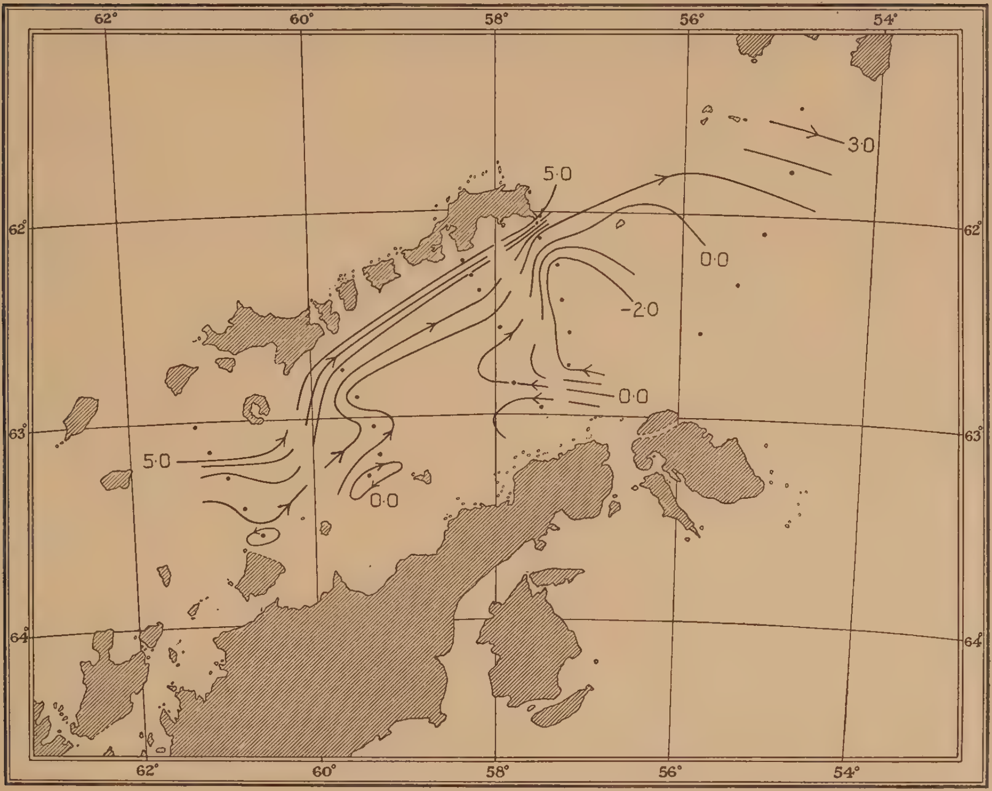

Fig. 56. Relative topography: 300 m., November 1929 and December 1930.

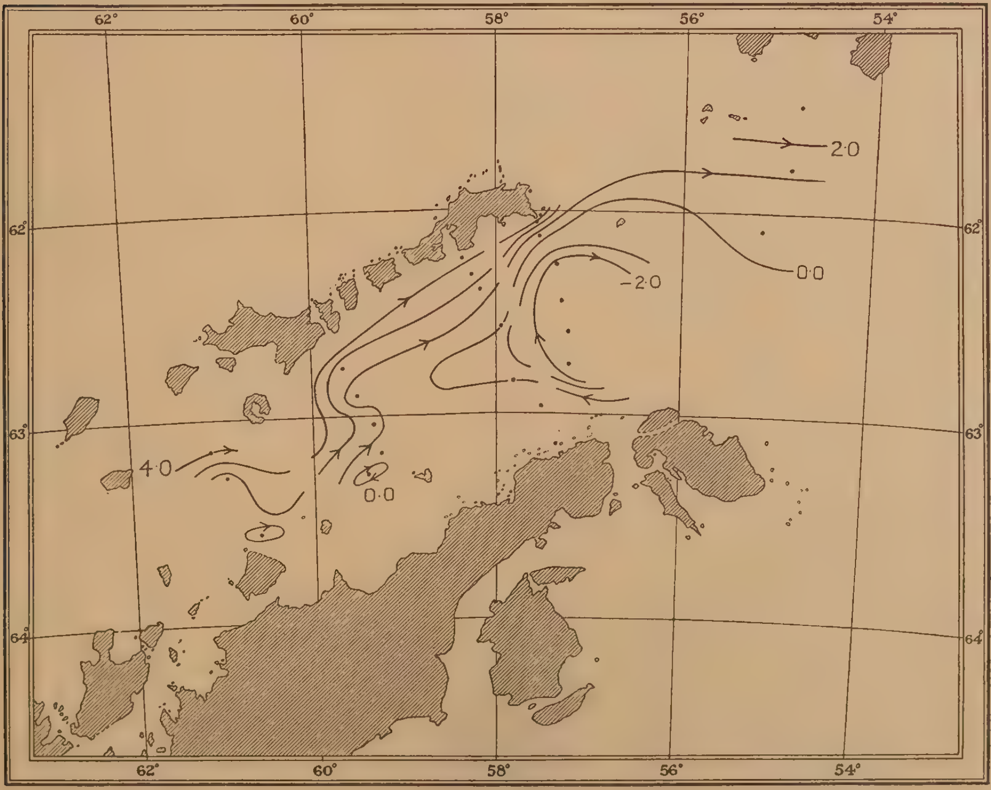

Fig. 57. Relative topography: 400 m., November 1929 and December 1930.

the existence of the belt of pack-ice which the whaling fleet finds in this position at the commencement of the season.

The representation of the surface currents of the Bransfield Strait from the present data is not complete, as the gaps between the lines of stations are too great. It must be regarded as being purely tentative and will no doubt be modified in the light of further data.

Between the cold surface layer and the bottom layer the relatively warmer and more saline layer exists in the Bransfield Strait at a level closer to the surface than in the sea outside. In November 1929 this warm intermediate layer was found in greatest amount at the west end of the strait between Snow and Smith Islands (maximum temperature, 1·07° C. at 400 m.) and between Low and Brabant Islands (0·55, 0·88 and 0·97° C. were recorded at 200–300 m.). In the same month, on the line between King George Island and Trinity Peninsula, this water extended from the station nearest the former island, St. WS 476, where a temperature of 0·75° C. was found at 300 m., to St. WS 480 nearly two-thirds of the distance across the strait, where a maximum temperature of 0·10° C. was found at a depth of 100 m. In December 1930 this warm intermediate layer was again in greatest amount at the south-west end of the strait, a temperature of 0·50° C. being recorded at 400 m. at St. 550 between Snow and Trinity Islands. On the other hand, all the other stations in the December 1930 survey show poorly developed

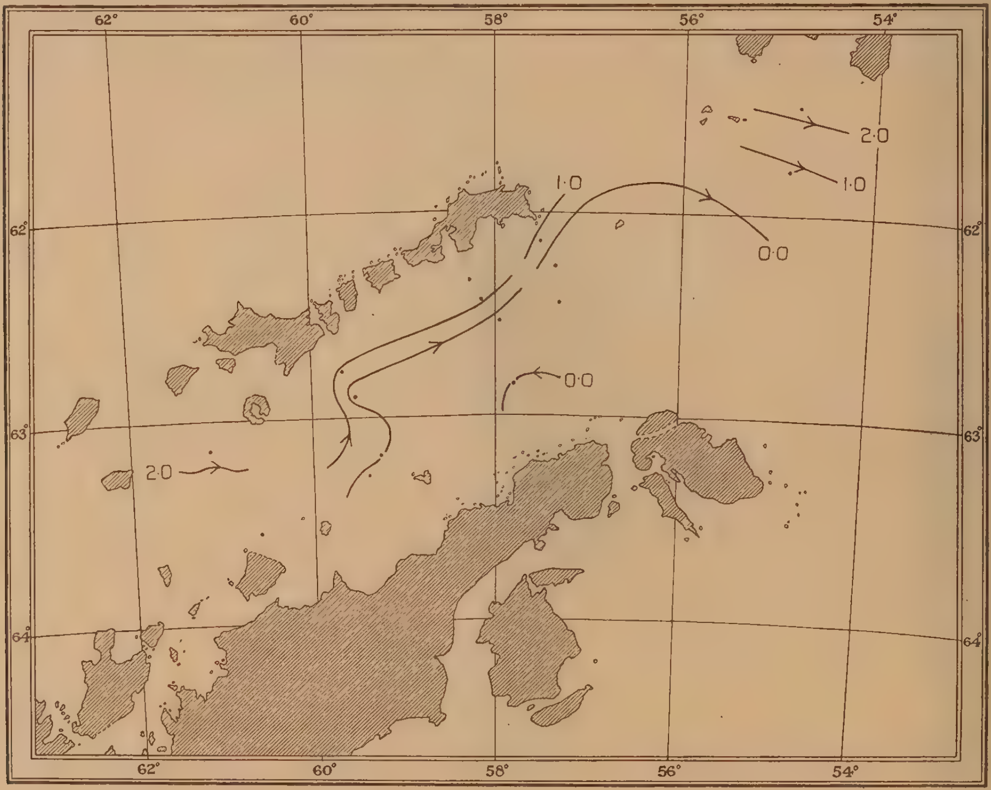

Fig. 58. Relative topography: 600 m., November 1929 and December 1930.

and minus temperature maxima, or none at all. Thus both the November 1929 and December 1930 observations show that the intermediate layer of warm deep water occurs at the south-west end of the strait in greatest amount; in the former year in November there is evidence for its presence over a large area between King George Island and Trinity Peninsula, whereas in December 1930 its existence over this area is not shown by well-marked temperature maxima. This is one of the difficulties encountered in combining material from two different years from an area where there are large variations from year to year in the physical characteristics of the water masses. It is possible that the warm intermediate layer present in the Bransfield Strait comes from both the west and the east, but the flow from the western end is undoubtedly much the greater.

Owing to the irregularity and steepness of the bottom contour there are not many observations below 600 m. to show the movement of the bottom water in the strait. As previously mentioned the movement of this water must be restricted by the submarine ridges. It might be supposed that the bottom water in the deepest parts of the deep basins would be stagnant. This, however, is far from the actual case, as the oxygen content at great depths shows. Thus at St. 543, approximately 15 miles from Cape Melville, the oxygen content *increases* from a depth of 600 m. to the lowest observation at 1500 m., where it is 6·43 c.c./litre, equal to a saturation of 76·3 per cent. This indicates that the bottom water must have been lately renewed, and movement of the bottom water must take place whenever the older water is replaced by a fresh supply of highly aerated water. In considering the movement of the bottom water within the strait, its mode of formation must be sought. H. U. Sverdrup, in his report on the waters of the North Siberian Shelf (1929), noted that instabilities were found in the surface layer and that the accuracy of the salinity and density determinations was such that these instabilities could not be otherwise than real. Moreover, the instabilities were only observed in the cold season when freezing takes place, and never in summer. A series of tables and graphs was given by the same author which show that the formation of these instabilities is clearly connected with the freezing processes. He also states (1929, p. 67) "The salinity of the water increases when ice forms, but the heavy brine does not sink immediately to the level of equilibrium, the sinking may be very slow and irregular and instabilities are so frequent that they are found in more than one-third of all cases. It is characteristic that the greatest numbers of instabilities are found in the earliest part of the winter when ice is freezing over many open lanes, while the greatest numerical values of the instabilities are found in the middle of winter, when the number of openings is smaller but freezing is more rapid". It is probable that a similar state of affairs occurs over the continental shelf of western Graham Land and Trinity Peninsula, and indeed over the shallower portions of the strait, in winter. In 1929, even in November, the surface values of temperature, salinity and density (σ_t) at St. WS 482 were − 1·18° C., 34·51 ‰ and 27·78, and in December 1930 at St. 547 the corresponding values were − 1·02° C., 34·53 ‰ and 27·79. These two stations were situated on the continental shelf of Trinity Peninsula. The freezing-point of sea water of salinity 34·50 ‰ is approximately − 1·88° C., and thus the surface water at these two stations has already been considerably warmed; it has also without doubt been diluted. Typical temperature, salinity and density values of the bottom water at 1500 m. in the deepest part of the strait were found at St. 543 to be – 1·72° C., 34·65 °/₀₀ and 27·91. The temperature of this water is higher than the freezing-point of water of salinity 34·50 °/₀₀. It is not difficult to imagine that in winter the surface salinity increases to a value greater than that of the bottom water and the temperature decreases to the freezing-point of such water, with the consequence that in areas where lanes of open water are found, sudden and intense freezing takes place with the formation of instabilities. In November and December we have noted that the water on the continental shelf is still very saline and cold from surface to bottom. In the winter months, water still heavier and of uniform temperature and salinity will be formed on the shelf. Within this layer intermittent sinking of water of higher salinity and lower temperature, formed by freezing processes, will take place and this heavier water will follow the slope of the bottom contour. In this way the bottom water in the strait is renewed and maintains its high oxygen content. This renewal of the bottom water will cause the water above to flow out of the strait, and it is significant that the oxygen content is at a minimum at a depth of 400–600 m. at St. 543 in the deepest part of the strait. This depth almost corresponds with the depth of the gap in the ridge south of Clarence Island through which the displaced water must flow.

Thus in the Bransfield Strait the formation of the bottom water is considered to take place in winter as a result of freezing processes mainly on the extensive continental shelf of west Graham Land and Trinity Peninsula. This mode of formation probably takes place also in other parts of Antarctica, and in particular *some* of the Weddell Sea Antarctic bottom water is undoubtedly formed on the continental shelf in the southern part of this sea as suggested by Brennecke (1921, p. 38). From the observations hitherto made it cannot be determined whether a renewal of the bottom water in the deep basins of the Bransfield Strait may also be affected by horizontal flow across the ridges, particularly across that to the east of the strait.

FEBRUARY 1929

The movement of the surface water in February 1929, as shown by the topography of the surface of the sea for the two principal lines of stations (Fig. 59), shows in general the two main features noticed for November 1929 and December 1930; there are, however, some modifications. The characteristic bend of the dynamic isobaths on the line from Livingston Island occurs almost as far across the strait as Astrolabe Island, so that the north-westerly flow of the surface water back to the north-easterly flowing current along the South Shetland Islands is found over a greater distance than in November 1929. The north-easterly flow on the South Shetland side of the strait is concentrated chiefly between the second and third stations from King George Island. A difference of height of 9·6 dynamic cm. occurs between these two stations, which are only 5·8 miles apart, and this corresponds to a surface current of 69 cm./sec. The gradient may be too great owing to considerable stray on the water-bottle wire at St. WS 383 causing the

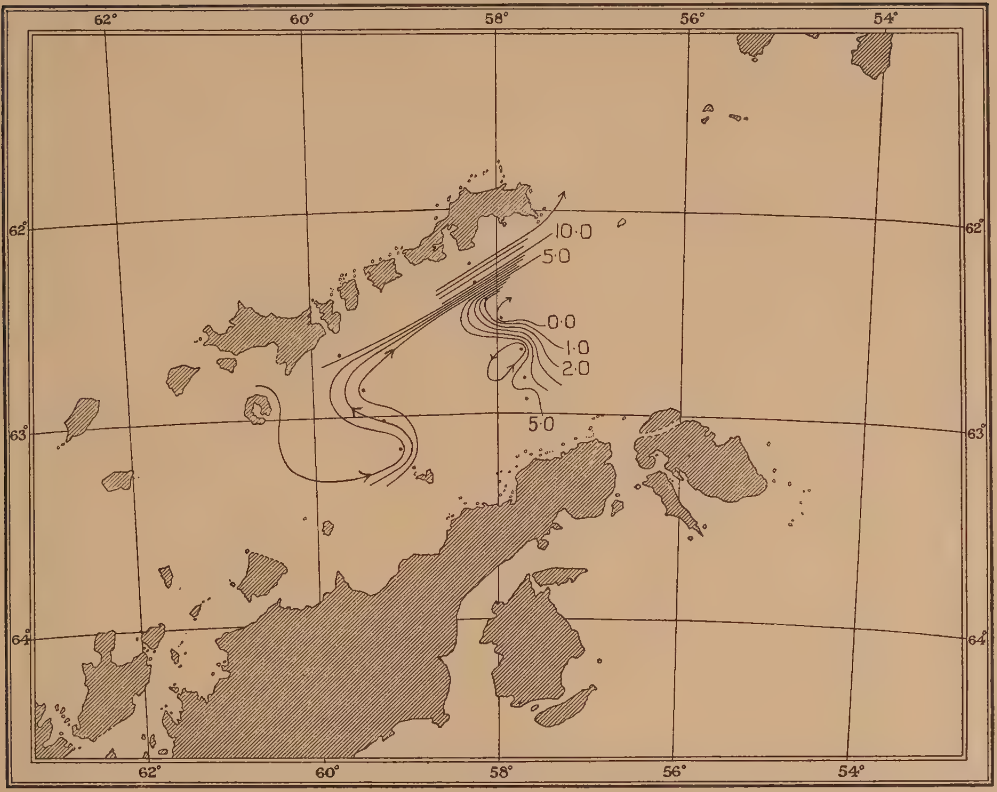

Fig. 59. Relative topography of the sea surface, February 1929.

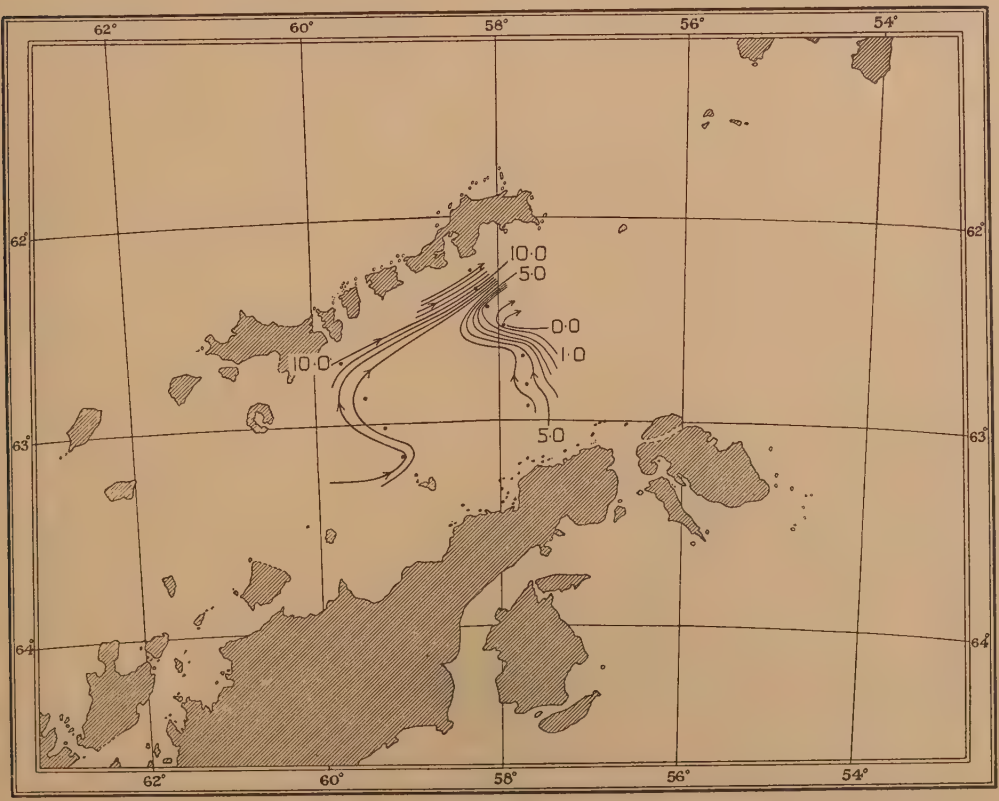

Fig. 60. Relative topography: 50 m., February 1929.

deeper samples to be obtained from lesser and incorrect depths. However, when the vertical section of the anomaly of specific volume was constructed, an attempt was made to correct for this by drawing the isosteres at this station closer to the surface, and using the interpolated values so obtained in the calculation of the dynamic depths to various surfaces at this station. There is no doubt that in February 1929 the current to the north-east in the strait was concentrated close to St. WS 383 in contrast to the widespread nature of this current in November 1929.

The lack of data between the lines from King George Island and Livingston Island gives an impression of the absence of movement in this area. In all probability whirls of movement actually do exist here, although it is impossible to furnish any proof. The influence of the Weddell Sea water on the current in the surface is shown by the northerly component of the dynamic isobaths towards King George Island. This influence is shown to occur somewhat farther into the strait and to stretch over a larger area across the strait than in November of the same year. A circular movement in an anticyclonic direction has been drawn round St. WS 386, which is in agreement with the very light water found in the upper layers at this station. Figs. 60 and 61 show the relative topography at 50 and 100 m.

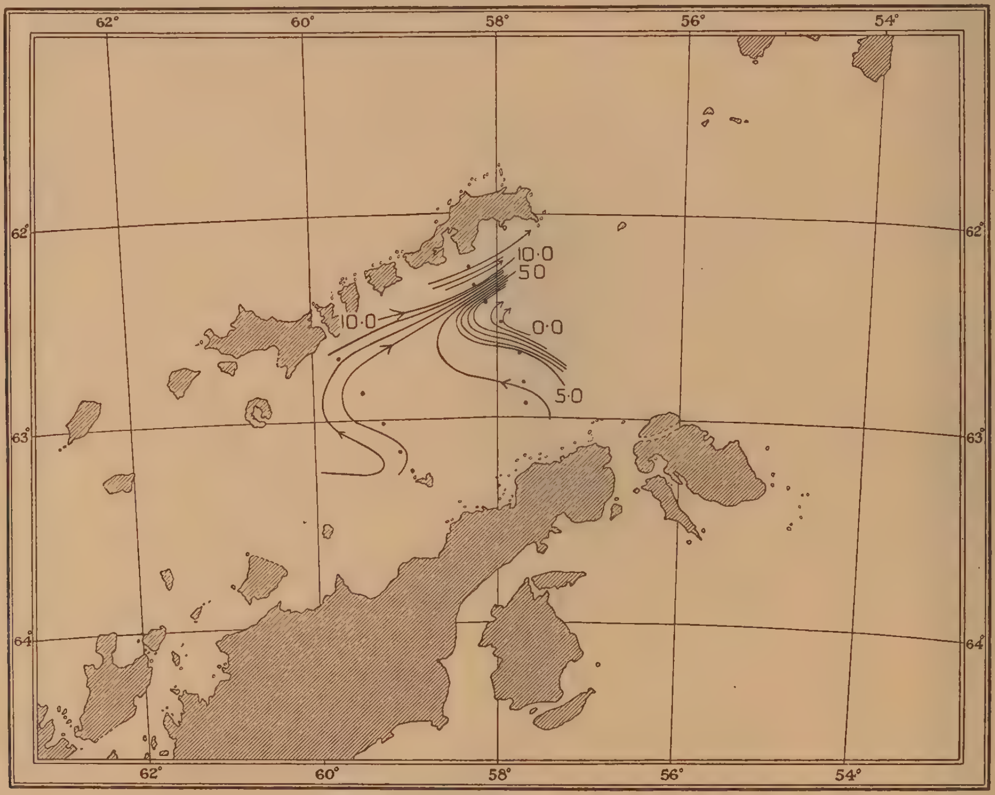

Fig. 61. Relative topography: 100 m., February 1929.

The movement of water in February 1929 (Figs. 62–5) differs considerably from that in November of the same year at depths below 200 m. In February at these depths very

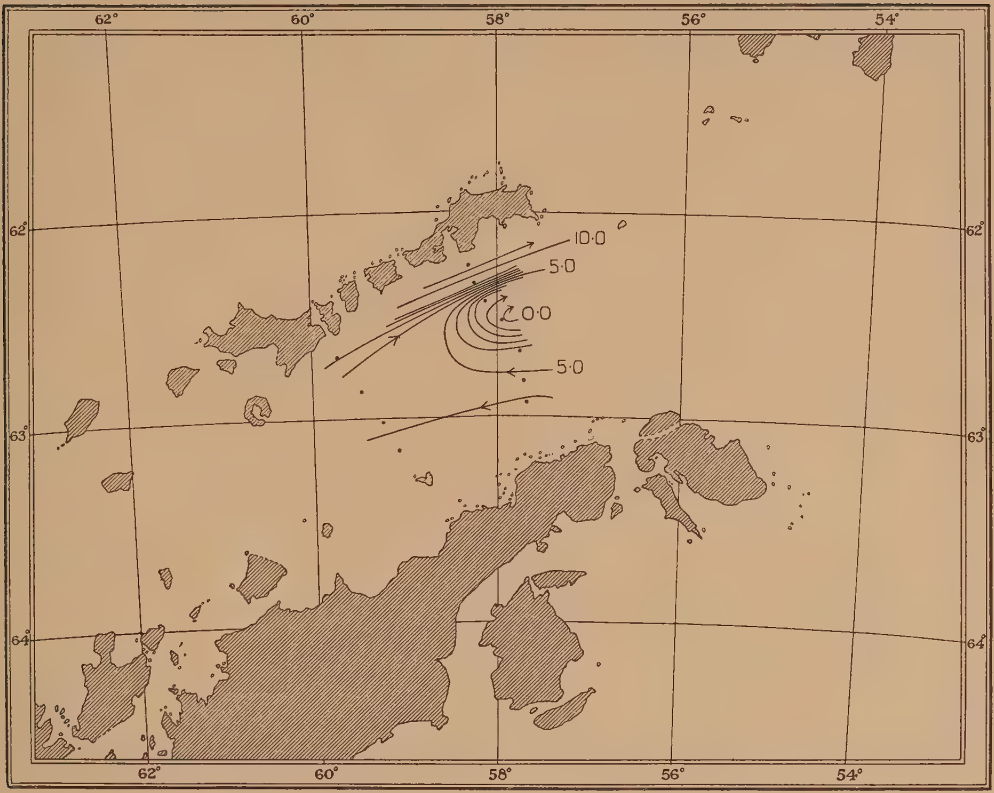

Fig. 62. Relative topography: 200 m., February 1929.

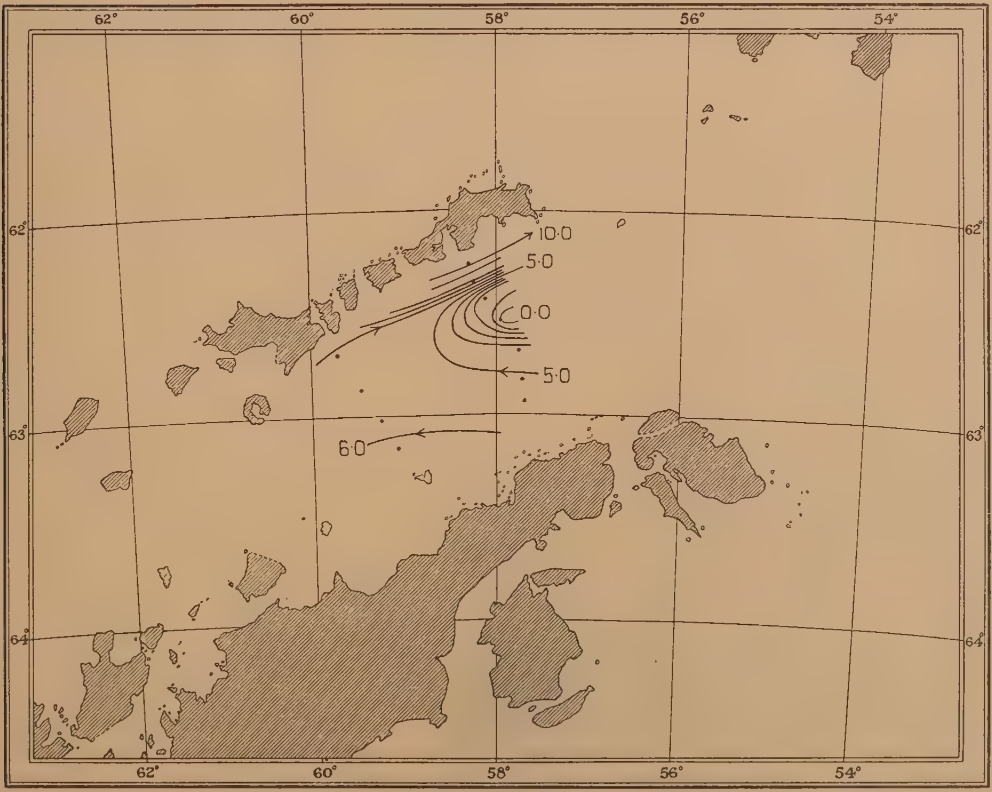

Fig. 63. Relative topography: 300 m., February 1929.

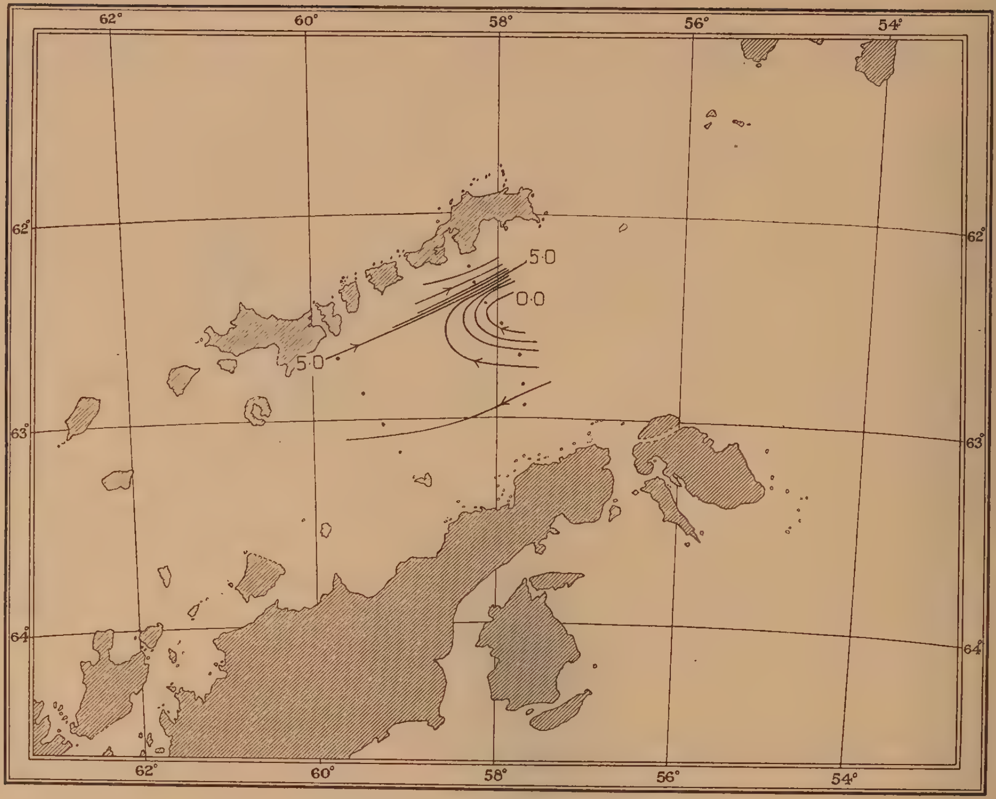

Fig. 64. Relative topography: 400 m., February 1929.

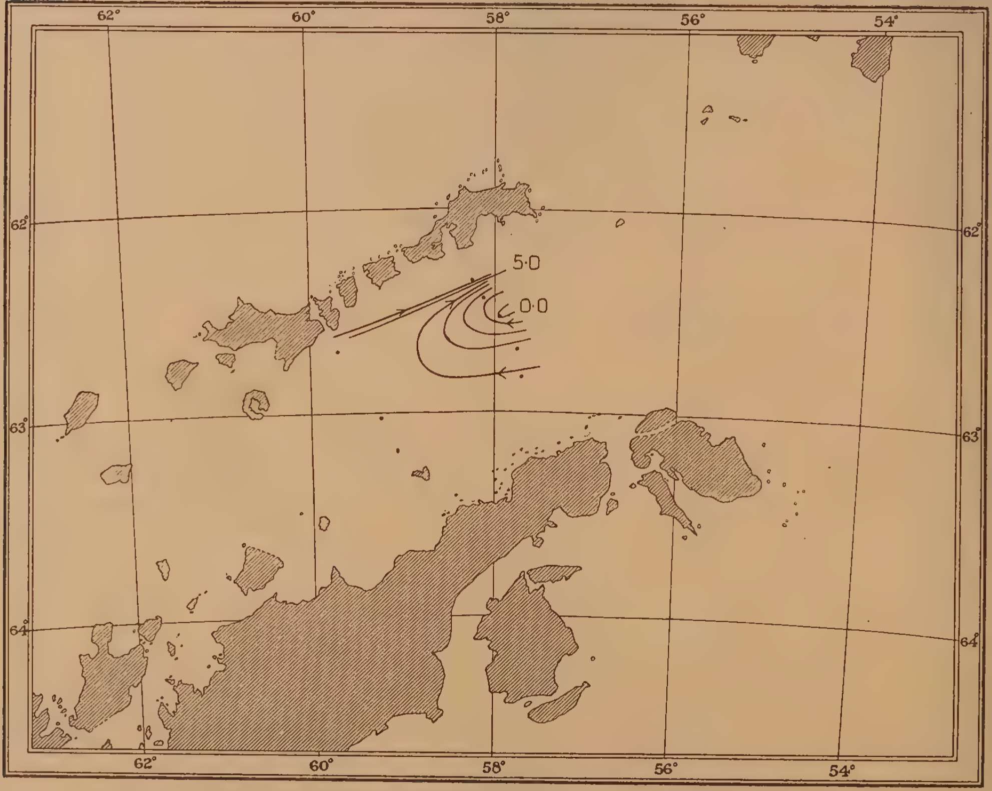

Fig. 65. Relative topography: 600 m., February 1929.

little flow is shown coming from the south-west except close to the South Shetland Islands, and the movement from the east end of the strait appears to predominate. This would account for the entire absence of any intermediate temperature maximum at all stations along the line from Livingston Island in February, except at St. WS 393, which is nearest to the South Shetland group and owes its positive temperatures between 100 and 300 m. to water from the south-west. In the discussion of the vertical sections of temperature and salinity attention was drawn to the great difference in the temperature-salinity diagrams of Sts. WS 393 and WS 392.

APRIL 1927

A discussion of the water movements in April 1927 is rendered extremely difficult by the conflicting observations on the line from King George Island to Trinity Peninsula. Attention has already been drawn to the fact that several salinities are abnormally high, probably due to the partial freezing of the sea water in the water bottles before a sample was withdrawn. The observations were made in very unfavourable conditions and it is probable that some of them are unreliable. When the vertical section of the anomaly of specific volume was constructed the salinity and temperature curves were smoothed, but the result as shown in the topographic charts is not happy. The levels of the various surfaces at St. 197 as shown in the charts are too low and those at St. 198 too high, with the consequence that the dynamic isobaths show a large whirl at all depths at St. 198. This is not at all likely in view of the results from other years. The characteristic bend of the dynamic isobaths along the line from Livingston Island which was noted in both of the surveys in 1929 is once more shown by the observations in 1927. For this season one chart only, that of the surface movements, is reproduced (Fig. 66).

It must again be stressed that in the absence of more complete data the movements of water as outlined above are to be regarded as purely tentative. It is recognized that the dynamic isobaths could have been drawn in other ways, and it is possible that future work will considerably modify the directions of the flow which have been deduced.

THE DIFFERENCES IN TEMPERATURE AND SALINITY IN FEBRUARY AND NOVEMBER 1929 ALONG THE NORTH-EASTERN LINE OF STATIONS

Two hydrological surveys were made in 1929: one in February when typical summer conditions were noted, and the other in November which reflected late winter or early spring conditions. It has already been noted in the discussion on water movement that the chief differences in these two surveys occurred at the north-eastern end of the strait. For this reason it was thought that a comparison of the observations in February and November at stations which were as nearly as possible in the same position on the line from King George Island would be of interest. The stations which are available are the following pairs: WS 382 and WS 476, WS 383 and WS 477, WS 384 and WS 478, WS 385 and WS 479, WS 387 and WS 480. Attention has previously been drawn to the fact that the observations at St. WS 383 are inaccurate owing to the great stray on the water-bottle wires. Consequently this station and its corresponding station in November, WS 477, have been omitted from this discussion. Table VII gives the difference, multiplied by 100, of the temperatures and salinities of the February stations from those of November. The figures in round brackets indicate that one or both of the observations in question have been interpolated.

From this table it will be noticed that at all stations the surface layer is warmer in February than in November, which is mainly a seasonal difference. The thickness of the layer of higher temperature in February is greater to the north-west (Sts. WS 382 and WS 476) and becomes thinner across the strait as far as Sts. WS 387 and WS 480; this is due to the greater development of the relatively warmer north-east current along the north-western side of the strait in February.

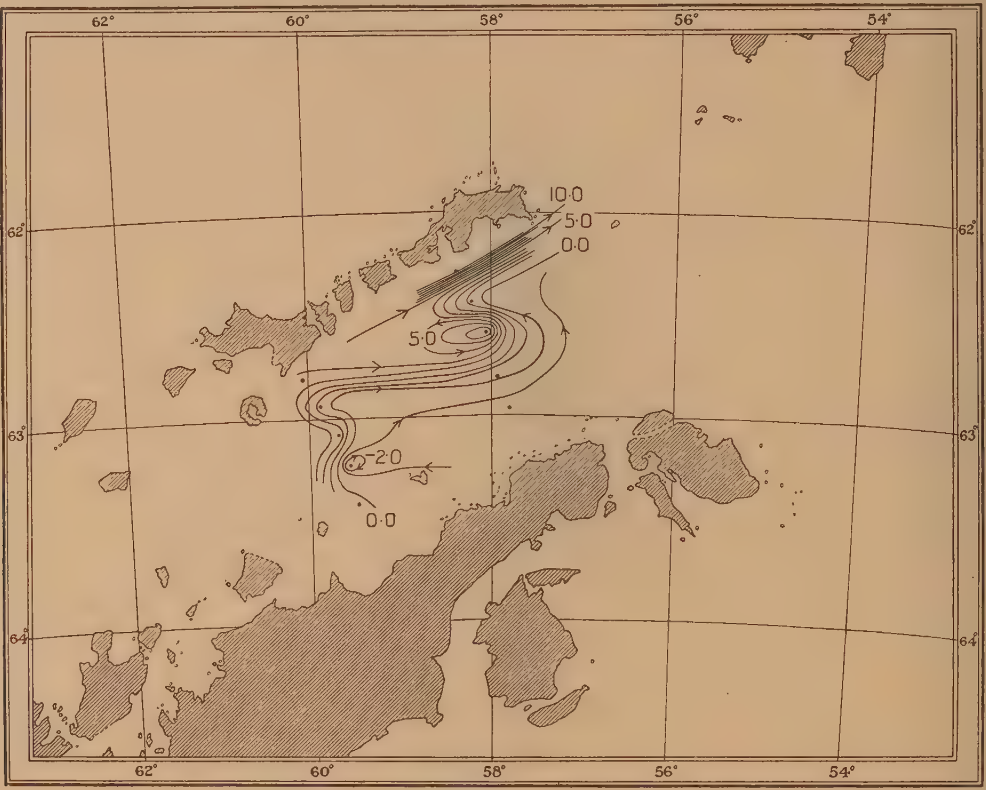

Fig. 66. Relative topography of the sea surface, April 1927.

At all stations the layer immediately below the surface layer is warmer in November, because of the increased thickness and spread across the strait of the warm deep water in that month. The excess of temperature in November over that of February is least marked at the station closest to King George Island, where a slight negative difference (February–November) is found only at 300 m. ($\Delta t = -0{\cdot}01^\circ$ C.). The thickness of the layer in which the November temperatures are higher increases at first and then gets less towards Trinity Peninsula and the layer is also closer to the surface in the same direction.

At all stations the layer below the warm deep water consists of warmer water in February than in November. This is probably due to the effect of the formation of Antarctic bottom water in winter and consequently the temperature of this layer is less in November than in February.

Close to the land at Sts. WS 382 and WS 476 the salinity in the 0–28 m. layer is higher in November than in February. This may be (i) because in November the surface water is not so much diluted by ice melting as in February; (ii) because in February the surface water may be showing the effect of dilution from the coast; or (iii) because the surface water just south of this position is moving in February at a higher rate than in November and consequently the surface water to the left of this current forms both a lighter and a deeper layer in February than in November.

Table VII

	WS 382–WS 476		WS 384–WS 478		WS 385–WS 479		WS 387–WS 480	
	Δ 100 t°	Δ 100 S ‰	Δ 100 t°	Δ 100 S ‰	Δ 100 t°	Δ 100 S ‰	Δ 100 t°	Δ 100 S ‰
0	227	– 11	299	3	220	– 29	207	– 12
10	226	– 10	302	3	220	– 28	192	– 13
20	213	– 11	291	3	205	– 11	129	(– 8)
30	174	2	202	10	184	11	38	– 8
40	153	5	149	18	177	14	2	– 9
50	152	8	134	18	87	4	– 20	– 20
60	142	9	106	23	55	3	– 53	(– 29)
80	139	8	57	13	25	0	– 96	(– 30)
100	133	11	3	17	11	9	– 137	– 26
150	82	– 4	– 83	5	– 21	5	– 87	(– 15)
200	(33)	(– 1)	– 96	– 3?	– 49	2	(– 61)	(– 9)
300	– 1	– 2	– 42	(5)	– 87	(3)	14	(– 8)
400	33	5?	(– 41)	4	– 15	1	– 1	(– 6)
600	—	—	19	(3)	23	0	12	(– 5)
800	—	—	32	1	24	1	—	—
1000	—	—	9	2	15	(2)	—	—
1500	—	—	10	6	—	—	—	—

At the next pair of stations to the south-east (Sts. WS 384 and WS 478) the water throughout, with the possible exception at a depth of 200 m., is more saline in February than in November. As far as the surface layer is concerned this cannot be due to ice melting in November because the greatest difference occurs at a depth of 60 m., whereas if it were due to ice melting in November the greatest difference would be at the surface itself. The dynamic charts for February, besides showing the Weddell Sea influence occurring farther across the strait towards King George Island than in November, also show an extremely steep gradient close to St. WS 383. In this case the velocity of the north-east current at St. WS 383 is very great in February and consequently the layers of equal density will slope down towards the north-west and up towards the south-east. Consequently in February denser water throughout the column will appear closer to the surface on the right-hand side of this current, i.e. at St. WS 384.

At the next pair of stations (Sts. WS 385 and WS 479) the 0–25 m. layer is much more saline in November than in February owing to a local accumulation of low salinity water in the upper layers in February. The salinity throughout is greater in November than in February at the pair of stations Sts. WS 387 and WS 480. As far as the surface layer is concerned this is due to the greater salinity of Weddell Sea water in November than in February.

Below the first 20 or 30 m. in the surface layer, the salinity is greater in February than in November at all stations except at the pair Sts. WS 387 and WS 480. With the exception of the pair Sts. WS 382 and WS 476 this is explained by the greater penetration of Weddell Sea water in February across the strait towards King George Island, which is shown by the dynamic charts. These charts, however, do not show the effect of mixing and sinking of water masses and hence the higher salinity of February over November in the position of St. WS 382 on the left-hand side of the strong north-east current may be due to mixture of the Weddell Sea water in February with the Bellingshausen Sea water on the western side of the strait.

The vertical sections show that in November the warm deep water, which lies immediately below the surface layer, was present over a greater area of the strait than in February; it has its maximum thickness at Sts. WS 476 and WS 477 on the northern side of the strait. If we compare the salinities of this layer for February and November we find that slightly more saline water is present at St. WS 476 in November than at St. WS 382 in February, which is due to the greater development of this water in November. At the next pair of stations (Sts. WS 384 and WS 478) the greater flow of warm deep water below the surface layer in November is shown chiefly by the higher temperatures of November over February in the layer approximately between 100 and 560 m., whereas only at 200 m. is the salinity higher in November. The dynamic charts show that the stations in the middle of the north-eastern line are affected in February by Weddell Sea water to a much greater extent than in November, when Sts. WS 478 and WS 479 are influenced by water from the south-west. The pair of stations closest to Trinity Peninsula (Sts. WS 387 and WS 480) show that throughout the whole column the salinity of November is higher than in February, no doubt due to the higher salinity of Weddell Sea water in November than in February.

At the stations in the north-western half of this line the bottom water is more saline in February than in November, whereas in Sts. WS 387 and WS 480, which are on the continental slope of Trinity Peninsula, the reverse is the case, i.e. November is higher than February. The life history of this water mass is not sufficiently known to enable a discussion of the variations in salinity of the bottom water to be made.

In the absence of data from the same months in other years the differences in temperature and salinity which have been noted above cannot be assigned solely to seasonal differences, as the influence of the great change in current movements in the strait from February to November may be due to variations other than seasonal. It is by no means certain that the same differences in temperature and salinity noted would be repeated every November and February, although it may seem probable that the current from the Weddell Sea is stronger and reaches farther westward in February than in November. Our material does not allow of a more detailed discussion of seasonal variations.

NOTE ON THE PRESENCE OF ICE IN THE BRANSFIELD STRAIT AND ON THE CURRENTS THROUGH THE STRAITS SEPARATING THE SOUTH SHETLAND ISLANDS

The operation of scientific vessels and the whaling fleet inside the Bransfield Strait has been limited to the short season November to April, and as far as our knowledge goes no ships have been present in this area in the southern winter. Much ice prevails in the strait in early spring and late summer and it is not known whether the strait is entirely closed to navigation in winter. According to a private communication from Mr Nielsen of the Hector Whaling Company, who has spent many whaling seasons at Deception Island, it is his opinion that the strait is never completely closed to navigation.

The approach of winter conditions in the Bransfield Strait is marked by the appearance of pack-ice at the north-eastern end of the strait; the ice then spreads across the strait at this end and down the Trinity Peninsula coast. When this accumulation of pack-ice has rendered whaling too difficult the whaling fleet has usually ceased operations for the season and has left the area. On their return in spring the whalers find, in years when not much ice is present, that the Bransfield Strait is either free or easily navigable at the end of October or the commencement of November. When, however, much ice is present the whaling factories have been considerably delayed in their endeavours to reach their anchorages in Deception Island or Admiralty Bay in King George Island, and may only be able to force their way into the strait in late November.

The position of the pack-ice in the south-western part of the strait in autumn and early spring appears to be regulated chiefly by the direction of the wind. Thus in the whaling season 1920–1 northerly and north-easterly winds prevailed from the end of November 1920 to the beginning of February 1921 and the ice which earlier had been carried north-east in calm and fine weather by the current close to the southern side of the South Shetland Islands was driven back in a south-westerly direction. The ice was still present in the eastern part of the Bransfield Strait in late February. On the other hand in the season 1921–2 the south-east side of the strait was free on November 25 1921 while the whole of the northern side was blocked, these conditions prevailing until January 1 1922, when the ice finally moved out in a *south-westerly direction*. The ice in the Bransfield Strait normally moves out of the strait to the north-east. In December 1923, contrary to usual, ice began to form in the sea east of Trinity Peninsula and Joinville Island towards Cape Melville. In March 1924 ice was moving to the south-west right into the middle of de Gerlache Strait. Had the north-east current not been flowing in the Bransfield Strait the whaling ships would have had to leave Deception Island as at certain times the ice pressed right up against the island. The easterly parts of the strait and the Trinity Peninsula coast were blocked throughout nearly the whole season. Thus the ice conditions inside the Bransfield Strait vary very considerably from year to year.

The pack-ice outside the strait on the northern side of the South Shetland Islands usually exists in a semicircular shape running north-east and south-west of these islands. This ice is usually still present until after the Bransfield Strait is either navigable or free from much hindrance.

When a succession of north-easterly winds is absent, or when no fresh accumulation of pack-ice is formed at the north-east end of the Bransfield Strait, the speed with which the ice moves out of the strait is remarkable. Thus on November 7 1923 the Bransfield Strait was reported full of thick pack-ice and large icebergs, whilst on November 16 only scattered ice remained which was no hindrance to navigation.

The whaling fleet has usually been able to work in and south of the de Gerlache Strait in January.

The *Antarctic Pilot* (1930), in giving the opinion of the whaling captains, states "...during November and the first half of December only a narrow strip of ice-free water exists from Martins Head [King George Island] to Deception Island, enabling vessels to pass through Nelson Strait and make Admiralty Bay; but in some seasons the bay itself is shut off by ice extending from Telefon Rocks [King George Island], in which case Port Foster, Deception Island, may be reached instead. This ice is sea ice and bergs drifting east-north-east close in to the south side of King George Island and thence to the south side of Elephant Island.... All this ice appears to come from outside Palmer Archipelago. The main pack comes eastward, past the south side of Deception Island, but a little may pass northward of the island" (p. 71). "The general current in de Gerlache Strait is to the north-east. Ice from de Gerlache Strait goes on north-eastwards through Orleans Channel, where many bergs are stranded..." (p. 84).

Two main current features are to be seen in the Bransfield Strait; part of the water from the Bellingshausen Sea enters the strait between the islands of Snow, Smith and Low and flows both north and south of Deception Island, where it makes a characteristic bend to the south-east before returning to the north-west, and then flows as a north-east set along the southern shores of the South Shetland Islands. The second great current movement comes from the Weddell Sea, bringing a large amount of cold dense water round Joinville Island which then spreads across the north-eastern end of the strait and down the coast of Trinity Peninsula.

The positions of some of the stations worked by the research ships have obviously been affected by these currents, which, however, are variable in strength. Thus during the time the R.R.S. 'Discovery II' was in the Bransfield Strait in April 1930 an allowance of 1–2 knots was made for the speed of the north-east flowing current close to the South Shetland Islands, during a passage across the strait from south-east to north-west. The result was that the final position of the ship was too much to the south-west and no allowance need have been made at all. A very considerable belt of pack-ice had been observed to the east and this may have had the effect of slowing down very greatly the north-east setting current. Similarly an accumulation of pack-ice to the south-west might also have had the same effect.

Normally, however, the north-easterly current piles up water against the South Shetland Islands and through the various narrow straits separating these islands. Thus the main part of the current along the South Shetland Islands sets to the north-east and some passes through the individual straits of the islands curving to the south-west on the northern shores of the islands, causing an anticlockwise circulation. This is shown diagrammatically in Fig. 67.

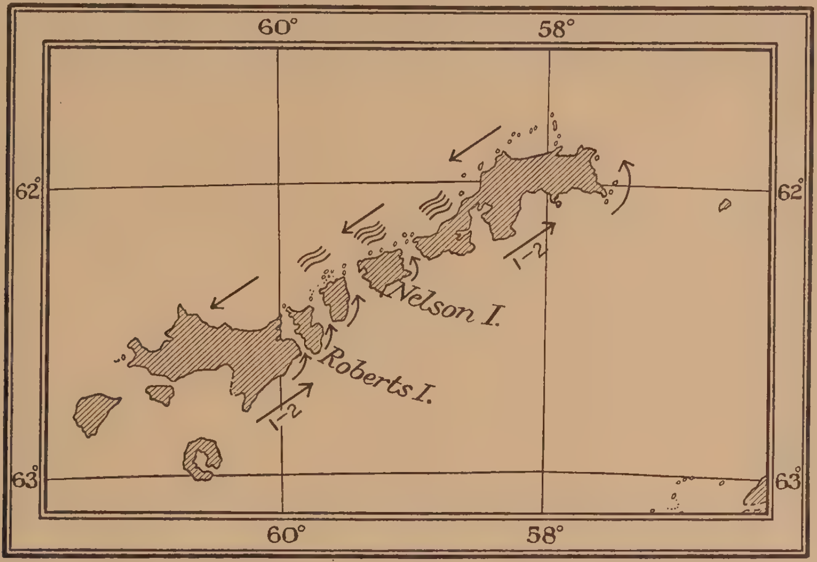

Fig. 67. Diagrammatic sketch of circulation round the South Shetland Islands and position of overfalls.

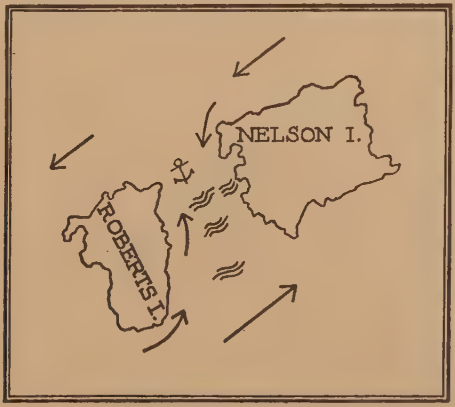

Fig. 68. Effect of north-easterly wind on currents in Nelson Strait.

The south-west going stream on the northern side of the islands has a tendency to flow southwards down the various straits, just as the north-east setting current in the main Bransfield Strait has also a tendency to pass through the individual small straits but in a contrary direction. Both currents then meet *outside* the narrow straits on the northern side of the South Shetland Islands, with the result that at the junction heavy overfalls are seen. When, however, north-easterly winds predominate, the south-west-going stream on the northern side of the island is considerably strengthened, with the result that this current overcomes the northerly set passing up the narrow straits, and passes into the individual straits. When this happens the two contrary directed currents meet *inside* the narrow straits and it is here that the heavy overfalls are now found.

In this latter condition a prominent line of demarcation is to be seen between the two currents, showing that on the western side of the narrow straits there is a north-going set and on the eastern side there is a south-going set. During the time the R.R.S. 'Discovery II' was lying at anchor in Nelson Strait we observed this last condition very well. A north-east wind commenced to blow and later the northerly set could be seen to be gradually overcome by the now strengthened southerly current.

SUMMARY

1. Previous workers have suggested the probability that the Bransfield Strait consists of an enclosed basin. This is confirmed and it is shown that two such basins exist, bounded by islands and submarine ridges. The effect of the bathymetric features is such that the strait is cut off from free circulation with the outside seas. As a result the temperature below the surface layer is abnormally low, the horizontal circulation is restricted very considerably at depths below those of the confining ridges and the amount of warm deep water within the strait is thus considerably less than exists outside, the lowest layer, consisting of Antarctic bottom water, being correspondingly increased. Temperature-salinity diagrams for stations both inside and outside the strait are given in illustration of the differences in composition of the water masses in this area.

2. Vertical sections of temperature, salinity and density show in general an increase of salinity and density and a decrease of temperature in the surface layer from the South Shetland Islands towards Trinity Peninsula. The amount of warm deep water is greatest at the south-west end of the strait and close to the South Shetland Islands, but decreases towards Trinity Peninsula. In February 1929, on the line from King George Island, thermal evidence of the presence of warm deep water was restricted to the station nearest the island, whereas in November of the same year the vertical section of temperature showed a wedge of this water reaching to at least within 24 miles of Trinity Peninsula.

3. Apart from the effects of the bottom topography the chief features of the circulation in the strait appear to be due to two main currents. At the south-western end water from the Bellingshausen Sea enters the strait between Low, Smith and Snow Islands and flows both north and south of Deception Island, finally appearing as a north-east going set close to the southern shores of the South Shetland Islands. At the eastern end of the strait a current of cold, more dense water, whose origin is the Weddell Sea, flows round Joinville Island and across the strait, some of it spreading down the Trinity Peninsula coast. In the available data there is one feature of the water which later forms the north-east set close to the South Shetland Islands, which appears to be permanent. The surface water after passing Deception Island makes a characteristic bend to the

south-east before returning to the north-west and then flows north-east past the South Shetland Islands.

4. Charts of dynamic topography were constructed according to a new method of Professor Helland-Hansen. By combining the hydrographic results of November 1929 and December 1930 in these charts the two chief currents and in particular the Weddell Sea influence in the strait were demonstrated. Charts showing the movement of water at the levels of 0, 50, 100, 200, 300, 400 and 600 m. are given for February 1929, November 1929 and December 1930, the two latter being combined. In February 1929 the characteristic bend of the lines of flow of the surface water on the line from Livingston Island extend almost as far across the strait as Astrolabe Island, whereas in November of the same year the south-easterly movement did not reach so far. In February 1929 the north-easterly current was concentrated about 10 miles from King George Island over a very narrow path, in contrast with the widespread nature of this current in November 1929. At depths below 200 m. the water movements in February 1929 differed from those in November of the same year in that the predominant movement appeared from the east in the former month. The results for December 1930 showed in particular the great influence of the Weddell Sea at the north-eastern end of the strait.

5. The temperature of the Antarctic bottom water inside the strait is much lower and the salinity slightly less than outside the strait. The Bransfield Strait Antarctic bottom water is formed *in situ* as a result of freezing processes in winter on the wide continental shelf of western Graham Land and Trinity Peninsula. This bottom water has a very high oxygen content which indicates its recent renewal.

6. No attempt at discussion of seasonal variation has been made owing to lack of suitable data, but the differences in temperature and salinity along a line of stations at the north-eastern end of the strait in February and November 1929 are discussed.

7. A note is added on variable movements of pack-ice in the strait and on currents between the South Shetland Islands.

In conclusion the author would like to express to Professor B. Helland-Hansen, Director of the Geophysical Institute, Bergen, Norway, his very great appreciation of the kindly help and advice given him throughout the preparation of this report and for valuable criticism of the manuscript.

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DISTRIBUTION OF THE MACROPLANKTON IN THE ATLANTIC SECTOR OF THE ANTARCTIC

By

N. A. MACKINTOSH, D.Sc.

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DISTRIBUTION OF THE MACROPLANKTON IN THE ATLANTIC SECTOR OF THE ANTARCTIC

By N. A. Mackintosh, D.Sc.

(Text-figs. 1–48)

INTRODUCTION

In the course of the oceanographical work which the Discovery Committee is conducting in the south, tow-nets of four different kinds have been used systematically for the study of the plankton. These are the 50 cm., 70 cm. and 1 m. nets, and the young-fish trawl. Of the four the 1 m. net, towed obliquely (N 100 B), is the most suitable for investigating the horizontal distribution of the larger plankton organisms. The following report is concerned with the samples taken by this net in the Antarctic surface waters, and its purpose is to find how the Antarctic environment of the whales is reflected in the distribution and variations of the macroplankton.

During the first commission of the R.R.S. 'Discovery' in 1925–7 the 1 m. nets were towed horizontally at routine stations, but it was found that a net towed obliquely from about 100 m. to the surface gives a better representation of the plankton, and the latter method was therefore adopted during the work of the 'William Scoresby' from 1927 to 1931 and of the 'Discovery II' in 1930 and 1931. The catches of the early horizontal nets, many of which have already been examined by Hardy and Gunther (1934), are not strictly comparable with those of the oblique nets; we are thus concerned here with the period 1927–31, and the stations taken into consideration are those in the true Antarctic water, together with a few on the north side of the Antarctic convergence. Of the species taken at these stations only one or two are confined to coastal regions, and we are in fact dealing with the plankton population of the open ocean.

During the period 1927–31 the majority of samples were collected in the neighbourhood of the Falkland Islands Dependencies, but lines of stations also extended from Bouvet Island in the east to a point west of Peter 1st Island in the Bellingshausen Sea. The positions of most of these stations are shown in Fig. 1.

The present report is based on the examination of about 600 samples from the 1 m. nets. From such a large number it is possible to obtain a great deal of information about the plankton, and the material is by no means exhausted by the results put forward in the following pages. It is the purpose of this report, however, not so much to elucidate the individual distribution of the various species as to examine the distribution of the macroplankton as a whole, and to distinguish individual communities whose constitution is dependent on the hydrological and geographical features of their environment.

THE PHYSICAL ENVIRONMENT OF THE ANTARCTIC PLANKTON

A summary account of the hydrology of the Atlantic sector of the Antarctic and the Bellingshausen Sea has been published by Mr G. E. R. Deacon (1933), and I am indebted to him and to Mr A. J. Clowes for much valuable information. There are four primary divisions of the oceans of the southern hemisphere: the Antarctic, sub-Antarctic, sub-Tropical and Tropical Zones. The Antarctic Zone is characterized by a cold, poorly saline surface layer of an average depth of about 200 m. This surface water flows away from the melting pack-ice to which its low temperature and low salinity

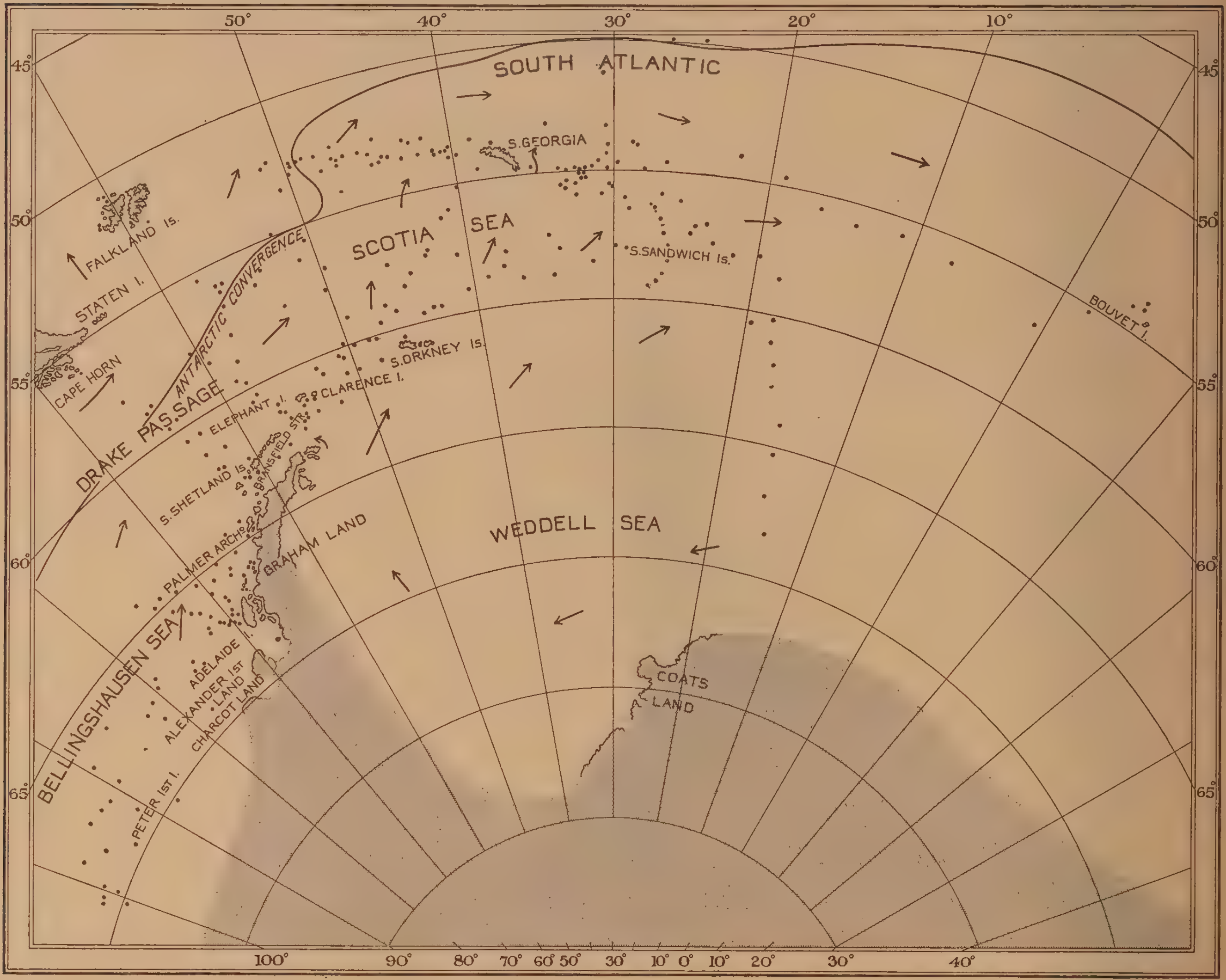

Fig. 1. The Atlantic sector of the Antarctic, showing stations at which N 100 B samples were taken. Stations included in intensive work around South Georgia and in the Bransfield Strait, and a line of close stations off Adelaide Island, are omitted. Surface currents are indicated by arrows.

are due, and gradually works northwards (with a strong easterly component) until it meets the more saline, but warmer and lighter water of the sub-Antarctic Zone, beneath which it sinks. The line along which this sinking takes place is the northern boundary of the Antarctic Zone and is known as the "Antarctic convergence".

Beneath the cold surface water is a much thicker layer of warmer water whose origin is in the North Atlantic or Pacific. There is a southerly component in the direction in which this water drifts, and when it reaches high latitudes it becomes cooled. Part of it rises to the surface to replenish the cold superficial layer, and the rest, which has been cooled but not diluted, sinks to form the Antarctic bottom water. This layer flows in a northerly direction. There is in fact a movement of cold water away from the pole at the surface and bottom, and towards the pole at intermediate depths. The warm intermediate layer is very rich in nutritive salts, and it is the upwelling of these salts into the cold surface layer which enables the richest plankton in the world to flourish in the Antarctic surface water.

In the lower latitudes of the Antarctic Zone the surface waters are drifting in an easterly direction, and Drake Passage may be described as a constriction in this drift. Graham Land and the associated islands and archipelagos, which form the southern promontory of this constriction, separate the Weddell Sea to the east from the Bellingshausen Sea to the west. North of the Weddell Sea lies the Scotia Sea, bounded to the west by Drake Passage and on all other sides by the Scotia Arc. The Scotia Arc is a loop of elevated land projecting eastwards into the Atlantic. It comprises—as existing land masses—Tierra del Fuego, Staten Island, the Shag Rocks, South Georgia, and the South Sandwich, South Orkney and South Shetland Islands. These, as Herdman (1932) has conclusively demonstrated, are connected by well-defined submarine ridges. The Burdwood Bank, to the east of Staten Island, forms part of the arc. Water passing eastwards through Drake Passage is deflected a little to the north-east and flows mainly through a gap in the Scotia Arc between the Burdwood Bank and the Shag Rocks. The Antarctic convergence passes through the middle of Drake Passage, and the water to the south of it is derived mainly from the Bellingshausen Sea.

In the Weddell Sea there is a clockwise circulation. This great bay in the Antarctic Continent receives water drifting westwards in the higher latitudes, and the flow is directed northwards and north-eastwards by the Graham Land Archipelago, and flows out as a very cold current towards the South Sandwich Islands and South Georgia. It joins the drift from the Bellingshausen Sea along a line running from the South Shetlands to South Georgia. The drift from the Weddell Sea carries with it much pack-ice and innumerable icebergs, so that in longitude 20 or 30° W the pack frequently extends far to the north of the South Sandwich Islands, while around 60 or 70° W it is never found very much north of the South Shetland Islands.

We are here dealing only with the larger plankton organisms and their horizontal distribution in the cold surface layer. These are the true Antarctic species. At greater depths we find species which are common to the deep waters of the Antarctic and the tropics, but with these we are not concerned.

METHODS

The construction and method of working the 1 m. oblique net have been fully described by Kemp and Hardy (1929). The essential points are as follows. It is a conical net with an opening 1 m. in diameter and the principal fishing part of the net is of stramin. The filtration of the stramin is roughly equivalent to that of silk bolting cloth having 15 meshes to the inch. "For oblique hauls open N 100 and N 70 were attached to the warp close together and 3 or 4 m. above the lead. With the ship steaming at 2 knots 200 m. was paid away, and as soon as this had been done hauling commenced. The rate of hauling was 10 m. per minute; each haul thus took 20 min. and the distance covered was two-thirds of a mile" (Kemp and Hardy, *loc. cit.*). By this method the net is fished obliquely from a depth of about 100 m. to the surface. The samples are preserved in formalin and stored in screw-top bottles.

The method of analysis of a plankton sample must be adapted to the type of net used. The vertical N 70, for example, is fished at a very uniform speed through an accurately measured column of water, the organisms caught are small and a comparatively refined technique can be used for quantitative estimations. The depth and speed at which the oblique N 100 is fished, however, are greatly affected by the difficulty of adjusting the ship's speed to varying weather conditions, so that precise quantitative comparisons between different samples are of questionable value, and a sufficiently accurate estimate may be obtained by less refined methods.

There is much variation in the richness of the Antarctic plankton, and a single haul may yield anything from a dozen to 200,000 organisms. Different methods must therefore be used for different catches. In small samples, containing up to 200 or 300 organisms, the total number of each species is counted without difficulty. Samples of average size, however, are much bigger than this, and a typical one might contain about 5000 organisms of which perhaps 4000 would be copepods. These have generally been treated as follows. The bulk of the formalin is strained off and the sample is washed into a glass dish with plenty of water. The large animals such as Amphipoda, large Siphonophora, Polychaeta and Salps can generally be quickly picked out. It is then necessary to go very carefully through the whole sample to find any of the species which are both small and present only in small numbers. It is very easy to miss such organisms as *Limacina* or the small siphonophore, *Dimophyes arctica*, whose presence or absence may be of some importance, and it is often advisable to turn over the whole sample several times before dealing with the more numerous organisms. The medium- and large-sized organisms such as Euphausians can all be picked out and counted if there are not more than (say) 60 or 70 of them. For the more numerous organisms subsamples are taken, and it may be necessary to take first a quarter or an eighth and count perhaps the Euphausians and Chaetognatha in that, and then to take anything from 1/16 to 1/256 to count the various species of Copepoda. For the Copepoda it has generally been customary to take a fraction which will contain 100 to 200 specimens. Even then there is a possibility of missing one or two of the rarer species. For taking sub-samples a rough and ready method has been found to be best. The catch is put in a large Petri dish and the water strained off until the sample has the consistency of a loose paste. It is well mixed up and the dish is shaken until the sample lies in a flat, even layer. It is then divided into quarters (or some other fraction), and a quarter is if necessary removed to another dish and further divided. The method is crude, but if carefully done can give surprisingly accurate results. An Einar Lea apparatus can be used, but with large organisms it is not more accurate than the method described above.

In the analysis of these samples no hard and fast line of procedure can be followed. The method must be suited to each sample, and the worker must endeavour to satisfy himself that he has not missed any of the rarer forms, and that he has estimated the approximate numbers of each species present. The analysis of a large sample of perhaps 20,000–30,000 organisms may occupy several hours, especially if there is a great variety of species. The smallest samples can be analysed in about 20 minutes.

The object of plankton work is to determine the nature of the plankton in a given area from the analysis of samples taken at selected points in that area. The inferences thus drawn are liable to certain errors which may arise from the distribution of the plankton itself in the water, from the method of collecting the samples, or from the method of analysing the samples. The subject has been dealt with by Hardy and Gunther (1934), whose remarks apply in a large degree to plankton collected by the N 100 B, and need be discussed only briefly here. The following are some points to be borne in mind: (i) Heterogeneous distribution of the plankton organisms may give a false impression of the fauna of an area. Thus allowances must be made for species which tend to a specially patchy distribution. (ii) Active avoidance of the net must sometimes take place, especially by such species as *Euphausia superba*. I have been able from the ship's side to watch a net being towed a few feet below the surface and passing through a shoal of this species. The Euphausians could clearly be seen to leap backwards out of the way of the approaching net. (iii) Variations in the speed of towing and depth of the net have already been mentioned. (iv) Where a number of species of many groups have to be quickly identified, complete accuracy is not always to be depended on. (v) Big catches of shoaling species such as *E. superba* and *Salpa* may swamp the sample and make an estimation of the other species almost impossible. Such catches must sometimes be disregarded except for the Euphausians or Salps themselves.

It may seem that some of these factors must lead to serious errors in the analyses, but Hardy and Gunther (1934) have shown that fluctuations in the numbers of the smaller plankton organisms are so great that an error of 50 per cent has little significance, and Hart (1934) points out, in connection with the analysis of samples of phytoplankton, that "in practice differences of 100 per cent and over are the smallest that can be regarded as of much significance". The same applies, possibly with even greater force, to the catches of the N 100 B, for although it may be too much to say that the important features of a sample are those which may be recognized at a glance, it is at least probable that the most obvious features will be the important ones, and that a significant difference in the numbers of a species in two samples will be great enough to swamp any minor inaccuracies which might arise from the methods of working the net and analysing the catch. At the same time conclusions must be drawn with caution, and the character of the plankton in a locality must not be judged from a single haul.

ORGANISMS IDENTIFIED

Samples taken by the N 100 B in the Antarctic contain a relatively small number of species, the majority of which are easily recognized. It is therefore possible for a single worker to familiarize himself with the common species and work straight through the samples, avoiding the delay which would be involved if all the catches were sorted and the groups distributed to a number of experts for separate identification. I have, however, received much assistance from Mr F. C. Fraser, formerly of the Discovery staff and now on the staff of the British Museum, and from Dr H. E. Bargmann, Mrs M. E. White and Mr A. H. Laurie, of the Discovery staff, each of whom has undertaken the analysis of a number of the samples. The Copepoda from some of the samples were identified by the late Dr Andrew Scott, who has also furnished a valuable reference set of named specimens. Other named specimens have been provided, of Amphipoda by Dr Barnard of the South African Museum, of Siphonophora by Capt. Totton of the British Museum, of Polychaeta by Mr Monro of the British Museum, and of Pteropoda by the late Miss Massy. Capt. Totton and Mr Monro have also kindly given me personal assistance from time to time. Under the guidance of Dr Kemp I have been able to identify the various species of *Euphausia*.

Even with such assistance it has not been possible throughout to identify by any means all the species which occur, but I have attempted to estimate the number of the following in every sample.

SIPHONOPHORA.
Diphyes antarctica, Moser.
Dimophyes arctica, Chun.
Pyrostephos vanhöffeni, Moser.

MEDUSAE.
Sibogita borchgrevinki, E. T. Browne.
Solmundella sp.

POLYCHAETA.
Tomopteris sp. (large).
Tomopteris sp. (small).
Vanadis antarctica (McIntosh).

ECHINODERMATA.
Auricularia antarctica, MacBride.

COPEPODA.
Calanus acutus, Giesbrecht.
C. propinquus, Brady.

COPEPODA (*cont.*).
C. simillimus, Giesbrecht.
Rhincalanus gigas, Brady.
Pleuromamma robusta (F. Dahl).
Metridia gerlachei, Giesbrecht.
Haloptilus ocellatus, Wolfenden.
Haloptilus sp.
Pareuchaeta sp.
Heterorhabdus sp.
Eucalanus sp.
Euchirella sp.
Candacia sp.

AMPHIPODA.
Parathemisto gaudichaudi (Guérin).
Primno macropa, Guérin.
Vibilia antarctica, Stebbing.
Eusirus antarcticus (Thomson).
Cyllopus spp.

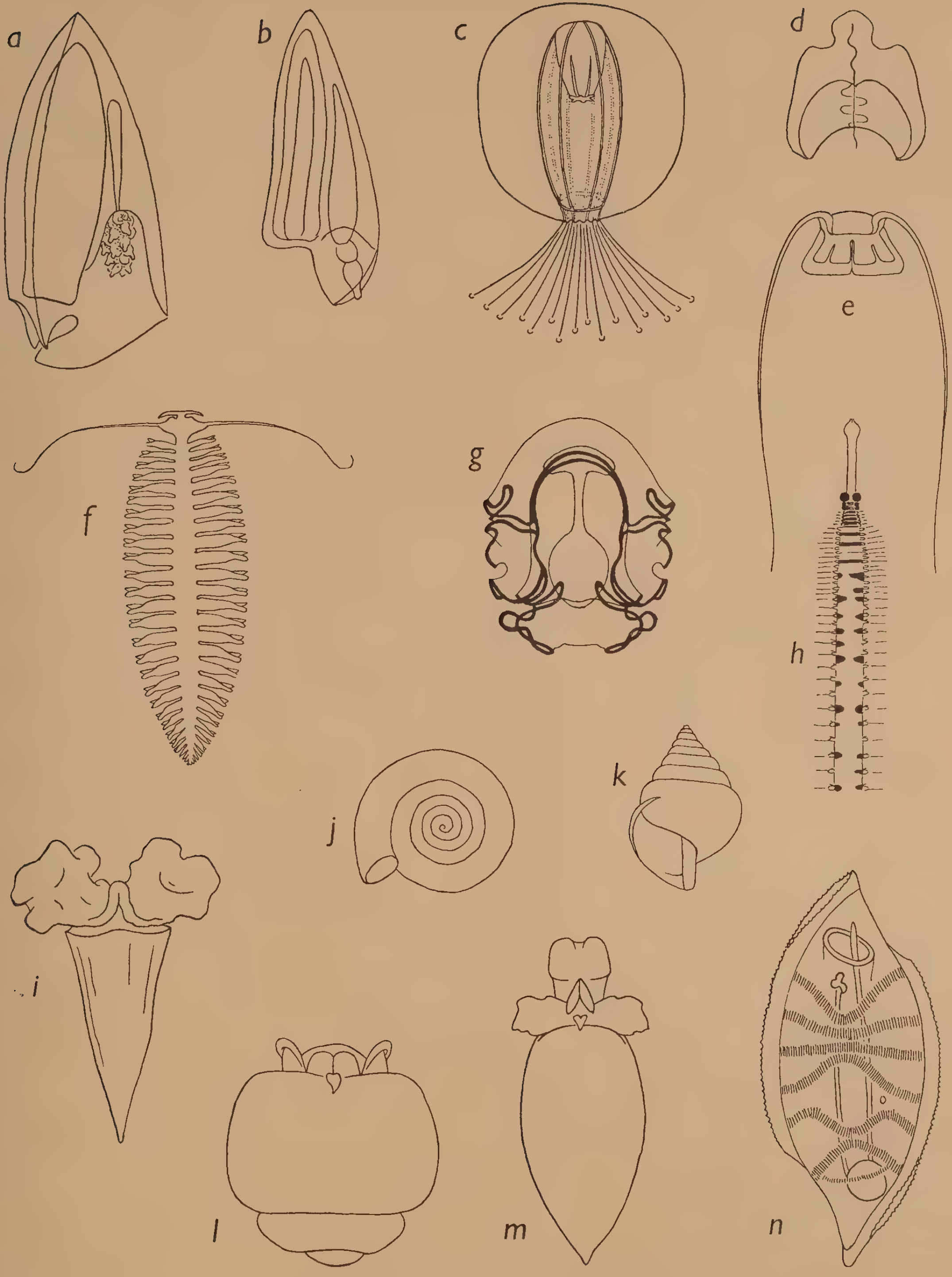

Fig. 2. Species of the Antarctic macroplankton.

a, *Diphyes antarctica*, anterior nectophore, × 2.
b, *Dimophyes arctica*, anterior nectophore (after Moser), × 7.
c, *Sibogita borchgrevinki* (after E. T. Browne), × 1$\frac{1}{3}$.
d, *Pyrostephos vanhöffeni*, nectophore, × 5.
e, *Solmundella* sp., × 2.
f, *Tomopteris carpenteri*, × 1.
g, *Auricularia antarctica*, × 8.
h, *Vanadis antarctica*, anterior portion, × 1.
i, *Cleodora sulcata*, × 3.
j, *Limacina helicina*, × 5.
k, *Limacina balea*, × 15.
l, *Spongiobranchaea australis*, × 4.
m, *Clione antarctica*, × 4.
n, *Salpa fusiformis* f. *aspera* (after Ihle), × 1$\frac{1}{2}$.

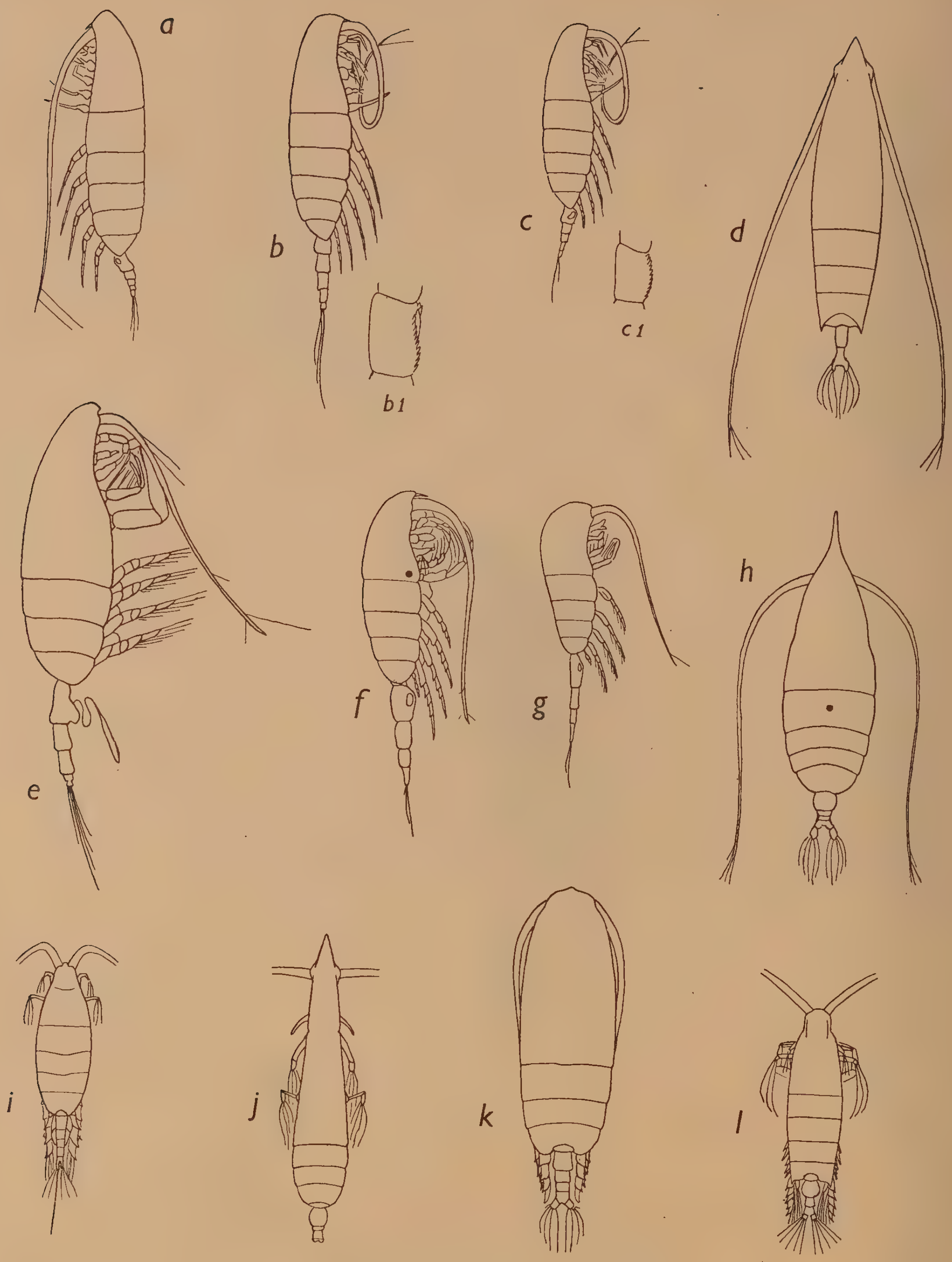

Fig. 3. Species of the Antarctic macroplankton.

a, *Calanus acutus*, × 8.
b, *Calanus propinquus*, × 8.
b 1, *C. propinquus*, basal joint of th. 5.
c, *Calanus simillimus* ♀, × 9.
c 1, *C. simillimus*, basal joint of th. 5.
d, *Rhincalanus gigas*, × 6.
e, *Pareuchaeta antarctica*, × 6.
f, *Pleuromamma robusta* (after Sars), × 10.
g, *Metridia gerlachei*, × 18.
h, *Haloptilus ocellatus* (after Wolfenden), × 6.
i, *Heterorhabdus* sp., × 8.
j, *Eucalanus* sp., × 8.
k, *Euchirella* sp., × 8.
l, *Candacia* sp., × 8.

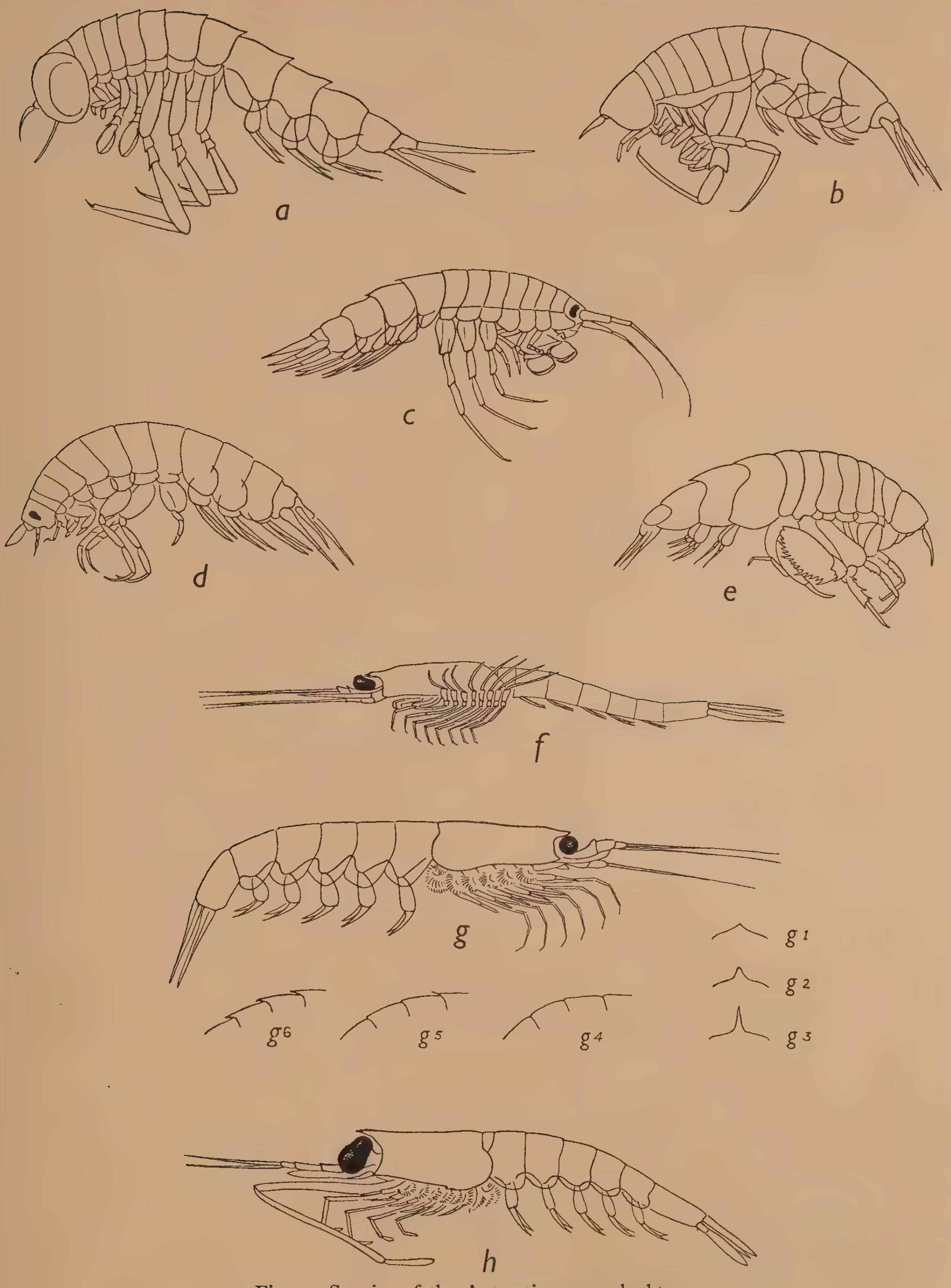

Fig. 4. Species of the Antarctic macroplankton.

a, *Parathemisto gaudichaudi*, × 4.
b, *Cyllopus* sp., × 3.
c, *Eusirus antarcticus*, × 4.
d, *Vibilia antarctica*, × 4.
e, *Primno macropa* (after Stebbing), × 4.
f, *Antarctomysis maxima*, × 2.
g, *Euphausia superba*, × $1\frac{1}{3}$.
g 1, Rostrum of *E. frigida*.
g 2, Rostrum of *E. vallentini*.
g 3, Rostrum of *E. triacantha* and *E. crystallorophias*.
g 4, Abdominal segments 3–5 of *E. frigida* and *E. crystallorophias*.
g 5, Abdominal segments 3–5 of *E. vallentini*.
g 6, Abdominal segments 3–5 of *E. triacantha*.
h, *Thysanoessa macrura*, × 3.

Mysidacea.
Antarctomysis sp.

Euphausiacea.
Euphausia superba, Dana.
E. frigida, Hansen.
E. crystallorophias, Holt and Tattersall.
E. triacantha, Holt and Tattersall.
E. vallentini, Stebbing.
Thysanoessa spp.

Mollusca.
Cleodora sulcata (Pfeffer).
Limacina helicina (Phipps).
L. balea, Möller.
Spongiobranchaea australis, d'Orbigny.
Clione antarctica, E. A. Smith.

Lunicata.
Salpa fusiformis f. *aspera* (Chamisco).

Chaetognatha.

Each of the above species and genera, and the group Chaetognatha will be treated in this paper as a separate unit. The specimens of *Solmundella* are likely all to be *S. mediterranea*. Specimens of *Haloptilus*, apart from *H. ocellatus*, may include *H. oxycephalus* and possibly others. *Pareuchaeta* sp. is generally *P. antarctica*, but may include *P. biloba*. *Heterorhabdus* sp. probably includes only *H. austrinus*. Some specimens of *Eucalanus* have been identified as *E. acus*, and some of *Euchirella* as *E. rostromagna*. *Candacia* sp. may include more than one species. The identity of *Eusirus antarcticus* has not been determined with absolute certainty. *Cyllopus* spp. includes *C. lucasi* and *C. magellanicus*, and *Thysanoessa* spp. includes *T. macrura*; *Antarctomysis* is probably *A. maxima*. There are two common Antarctic species of *Tomopteris*, *T. carpenteri* and *T. septentrionalis*. When adult the former can always be distinguished from the latter by its greater size, but the identification is otherwise difficult. Those distinguished in this paper as "large *Tomopteris*" are nearly always *T. carpenteri*, and those included under "small *Tomopteris*" are generally *T. septentrionalis*, but may include an unknown proportion of immature *T. carpenteri*. The vast majority of the Chaetognatha are *Eukrohnia hamata*, but *Sagitta gazellae*, *S. maxima*, and *S. planctonis* occur in small numbers. Naturally those units identified only as genera or as a group have little value compared with those identified as species, but nearly all of them occur only in small numbers. Only *Thysanoessa* and the Chaetognatha appear in large numbers, but immature specimens, especially of the former, make up so high a percentage of these two units that complete specific differentiation would have been very difficult, and would have greatly prolonged the period occupied in the analysis of the samples.

For description of the species shown in the above list the following authorities may be consulted.

Moser (1925): *Diphyes antarctica*, *Pyrostephos vanhöffeni*.
Chun (1897): *Dimophyes arctica*.
Browne (1910): *Sibogita borchgrevinki*.
Benham (1921): *Vanadis antarctica*.
MacBride (1912, 1920): *Auricularia antarctica*.
Wolfenden (1908): *Calanus acutus*, *C. propinquus*, *C. simillimus*, *Metridia gerlachei*.
Schmaus and Lehnhofer (1927): *Rhincalanus gigas*.
Sars (1903): *Pleuromamma robusta*.
Wolfenden (1911): *Haloptilus ocellatus*.
Barnard (1932): *Parathemisto gaudichaudi*.

Stebbing (1888): *Primno macropa, Vibilia antarctica.*
Stebbing (1906): *Eusirus antarcticus.*
Tattersall (1908): *Euphausia superba, E. crystallorophias, E. triacantha, E. vallentini.*
Hansen (1913): *Euphausia frigida.*
Massy (1920): *Cleodora sulcata.*
Massy (1932): *Limacina helicina, Spongiobranchaea australis.*
Bonnevie (1913): *Limacina balea.*
Eliot (1907): *Clione antarctica.*
Ihle (1912): *Salpa fusiformis* f. *aspera.*

Other species which occur from time to time, but which are mostly uncommon and are disregarded here, are certain Medusae, Ctenophora, Polychaeta, Ostracoda and one or two small Amphipoda.

This method of taking only certain units into consideration might be criticized as arbitrary; but the use of any net with a particular aperture and mesh is also arbitrary, and the best we can do is to study certain organisms, and find from them what we can of the general behaviour of the macroplankton.

CRUISES IN THE PERIOD 1927–31

The following notes are not perhaps essential to the purposes of this paper, but since the catches taken in the various cruises will not be dealt with in strict chronological order, I have felt that a brief statement of the order in which the stations were taken might be useful for occasional reference.

During the first commission of the 'Discovery' and the associated work of the 'William Scoresby', the 1 m. nets were towed in horizontal flights of three. On the return of the 'William Scoresby' to South Georgia in February 1928, and in all subsequent work, the oblique 1 m. net (N 100 B) was used at all routine stations. The greater part of the plankton work in the Antarctic has been done during the summer months from October to April, and it will therefore avoid confusion if we speak of summer seasons (which are equivalent to the whaling seasons) rather than of years, and say that the regular work with the N 100 B began in February 1927–8. Full details of all the stations carried out, together with charts, are published in the Station Lists.[1]

Season 1927–8 (Figs. 5 and 10). The work of the 'William Scoresby' began with a line of stations from the Falkland Islands to South Georgia (WS 139–43[2]) and was followed by a survey of the South Georgia whaling grounds (WS 144–93). A line of stations was then worked from South Georgia to the vicinity of the South Shetlands and another line northwards to the Burdwood Bank and the Falkland Islands (WS 196–205).

Season 1928–9 (Figs. 6, 7, 11 and 15). The ship was next engaged in a trawling programme, but plankton work was resumed in August 1928. After a line of stations from the Falkland Islands to South Georgia (WS 253–6), the South Georgia survey was repeated, with the exception of the two southern lines, in incessantly adverse weather conditions, during the end of August and the greater

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[1] *Discovery Reports*, III, pp. 1–132, and IV, pp. 1–230.

[2] Where a line of stations crosses the Antarctic convergence, the station numbers given here in brackets include only those taken in Antarctic water together with the first station on the north side of the convergence if it is still quite close to the latter. Stations at which the N 100 B was not used are omitted in the charts shown in Figs. 5–17.

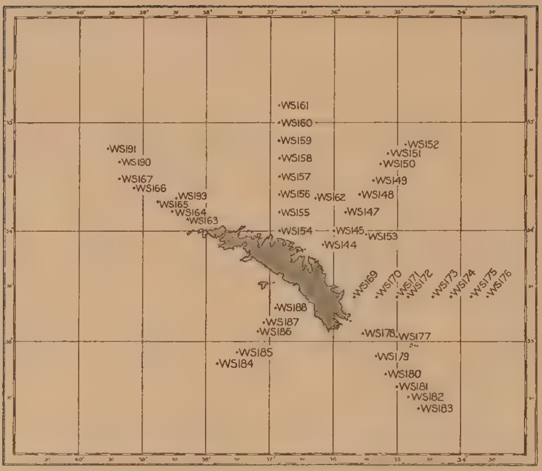

Fig. 5. South Georgia survey, February–March 1927–8.

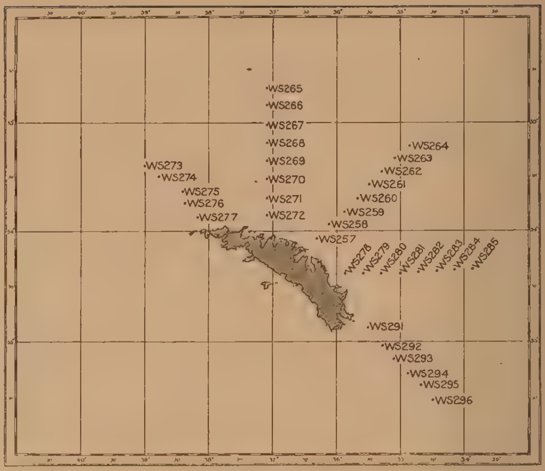

Fig. 6. South Georgia survey, August–October 1928–9.

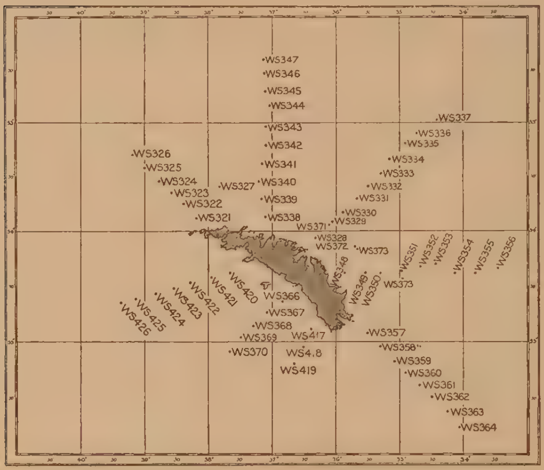

Fig. 7. South Georgia survey, December–January 1928–9.

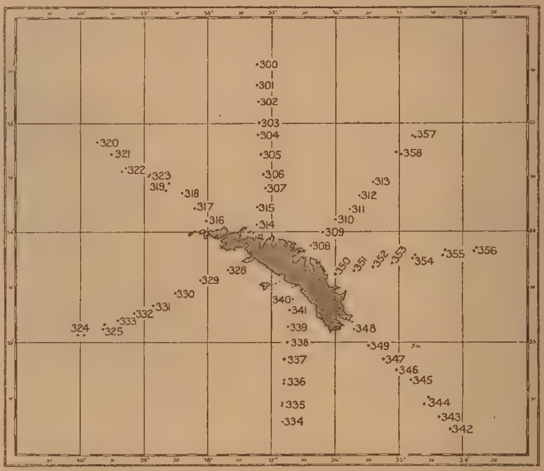

Fig. 8. South Georgia survey, January–February 1929–30.

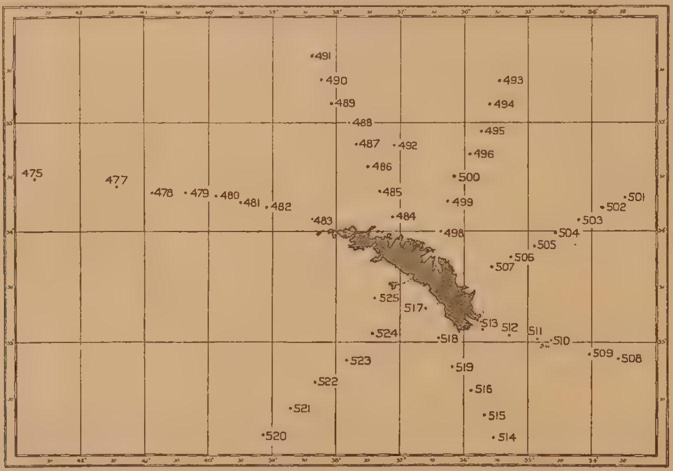

Fig. 9. South Georgia survey, November 1930–31.

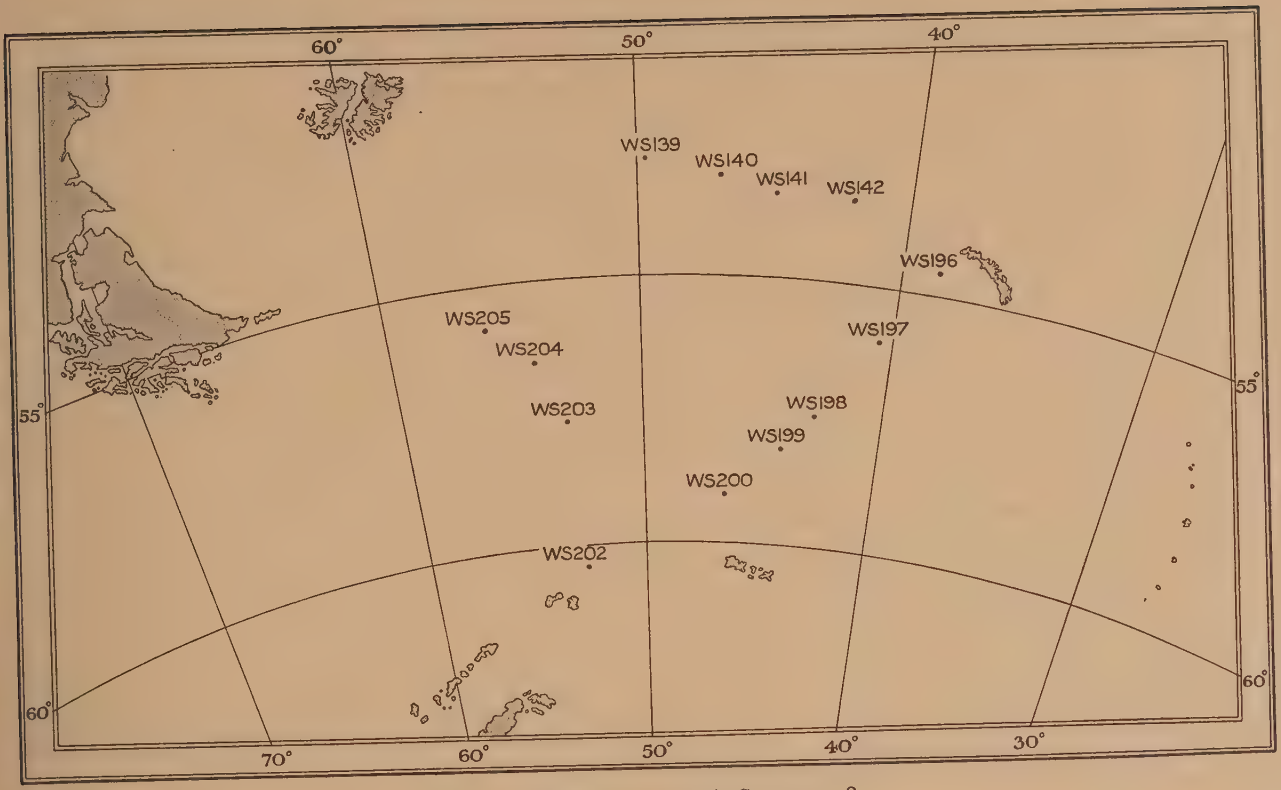

Fig. 10. Stations in the Scotia Sea, 1927–8.

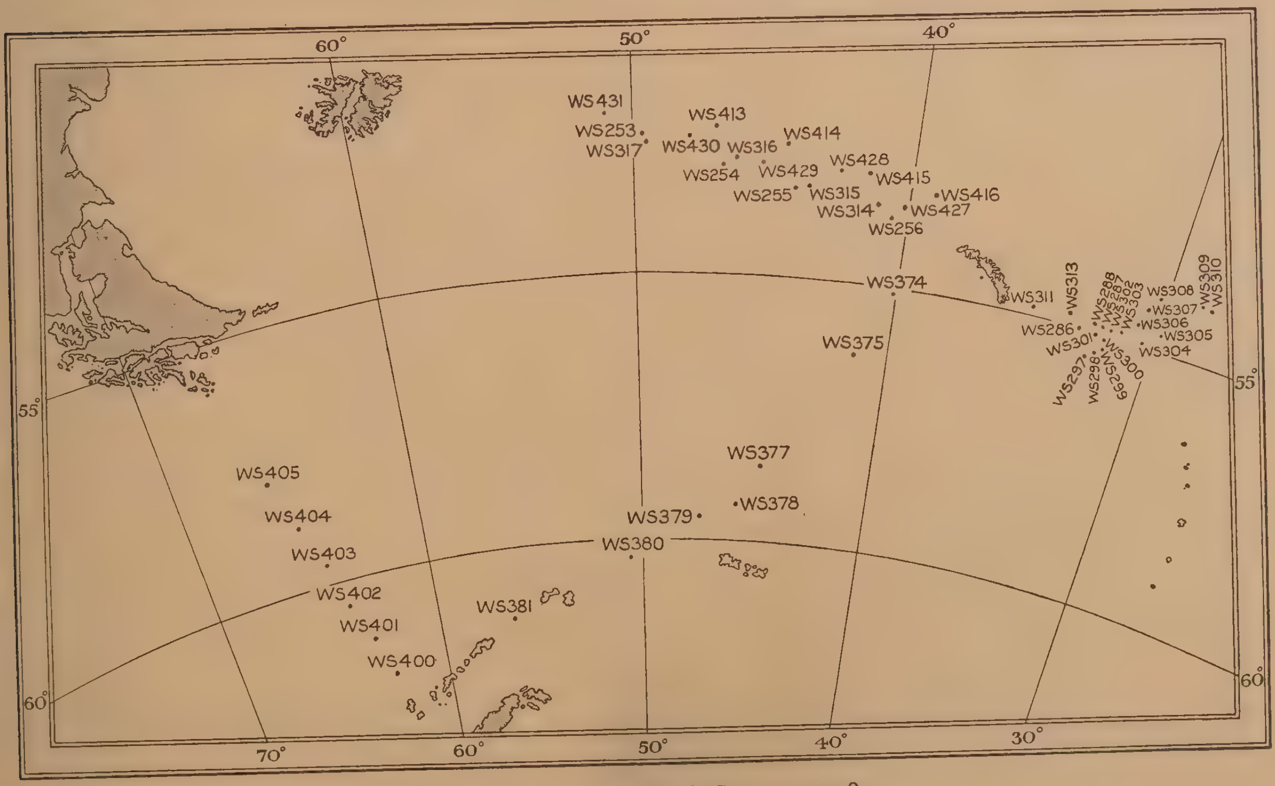

Fig. 11. Stations in the Scotia Sea, etc., 1928–9.

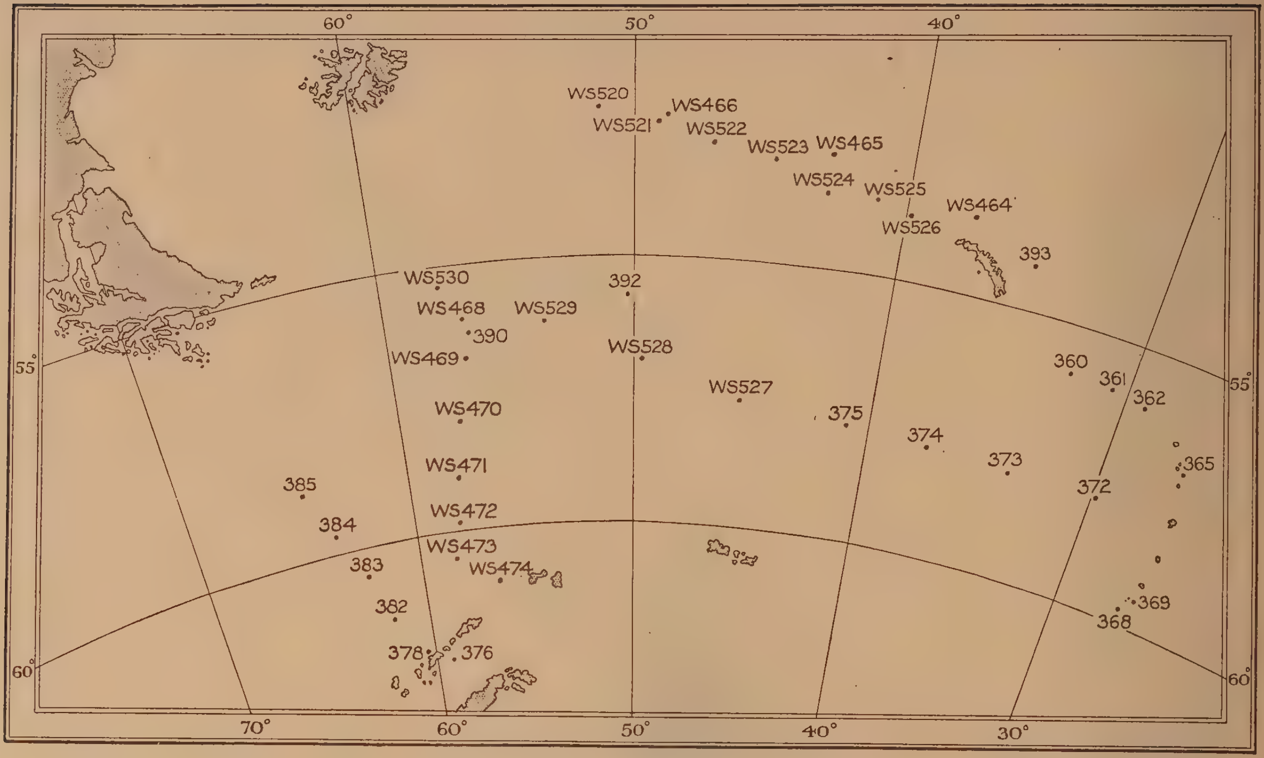

Fig. 12. Stations in Scotia Sea, etc., 1929–30.

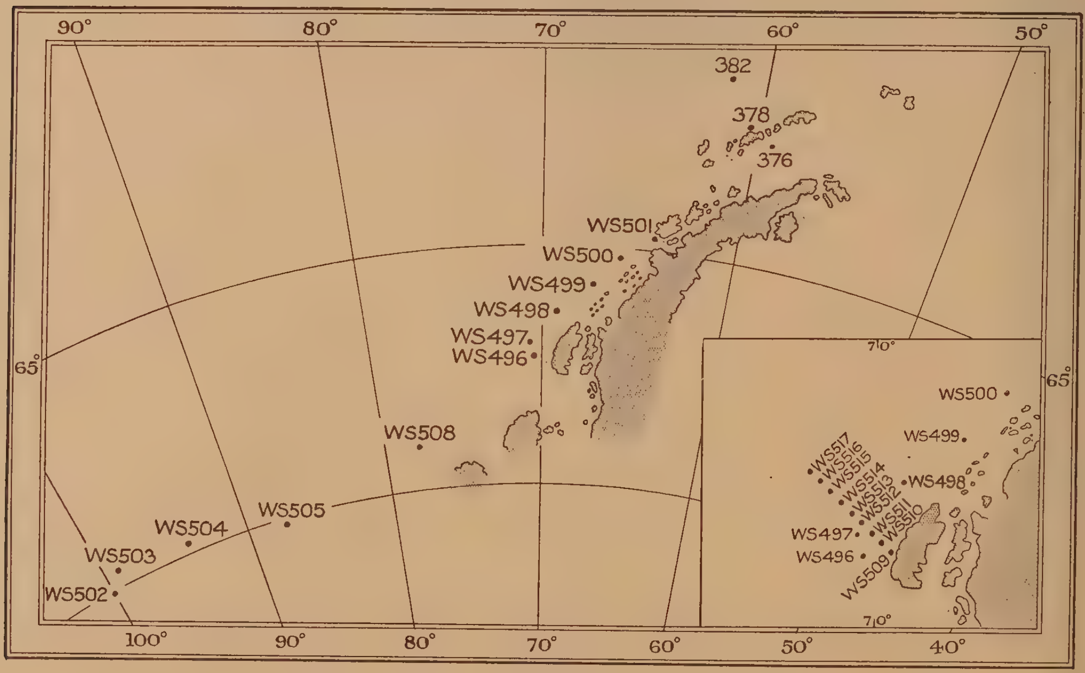

Fig. 13. Stations in Bellingshausen Sea, 1929–30.

part of September (WS 257–96). A series of stations was then worked along the ice-edge to the south-east of the island (WS 287 and 288, and 297–310), and a second line was laid from South Georgia to the Falkland Islands (WS 314–17). After the return of the ship to South Georgia a complete survey was again carried out (WS 321–72 in December–January), and she proceeded to the South Shetland Islands (WS 374–81), where intensive work was done in the Bransfield Strait in February (WS 382–99). A line of stations was then taken across the Drake Passage to Cape Horn (WS 400–5), and then to South Georgia *via* the Falkland Islands (WS 413–16). Here two more lines of stations were taken in April on the south side of the island (WS 417–26) and a fourth line between South Georgia and the Falkland Islands (WS 427–31). The season closed with the ship's departure from South Georgia to Capetown, when two more stations were taken in Antarctic water (WS 434 and 435).

Season 1929–30 (Figs. 8, 12, 13 and 16). The 'William Scoresby' returned to South Georgia in October and proceeded thence to the Falkland Islands (WS 464–6). From November to February she visited the Bellingshausen Sea, and, though primarily engaged in other work, was able to continue some plankton investigations. These included a line of stations from the Falkland Islands to the South Shetlands (WS 468–74), intensive work in the Bransfield Strait (WS 476–93), various stations off the coast of Adelaide Island and the Biscoe Islands (WS 496–501), five stations along the ice-edge in the Bellingshausen Sea as far as 100° W (WS 502–8), and a line of stations at short intervals running north-westward from Adelaide Island (WS 509–17). The ship then returned in February to the Falkland Islands. In the meantime the 'Discovery II' reached South Georgia in January, and proceeded with the usual survey of the whaling grounds (Sts. 300–59). This was followed by a visit to the South Sandwich Islands where six plankton stations were taken (Sts. 360–9), and some time was spent in topographical surveying. In March a line was begun from the Sandwich group to the Burdwood Bank (Sts. 372–5), which was later completed by the 'William Scoresby' (WS 527–30) after the latter ship had worked more stations between the Falkland Islands and South Georgia (WS 520–6). In April the 'Discovery II' visited the South Shetlands, took a station in the Bransfield Strait (St. 376), a line across the Drake Passage (Sts. 378–85), and two more stations on the way back to South Georgia (Sts. 390 and 392). The 'William Scoresby' now left for Europe and the 'Discovery II' for Capetown. At the beginning of the voyage an attempt was made with the latter ship to carry out continuous observations throughout a 24-hour period near South Georgia. Flights of six closing N 100 B were to be taken every four hours (St. 393), but the series was interrupted by bad weather before it could be completed. One more station (St. 394) was taken in Antarctic water on the way to the Cape.

Season 1930–1 (Figs. 9, 14 and 17). The 'Discovery II' sailed from Capetown in October, reached the ice-edge south of Bouvet Island (Sts. 452–60) and followed it westwards to South Georgia (Sts. 462–72). A 24-hour station with closing N 100 B (St. 461) was worked off the ice. The South Georgia survey was repeated in November (Sts. 475–525), and a cruise to higher latitudes begun. The ship followed the ice-edge from a point near the Sandwich group to the Bransfield Strait (Sts. 528–41), taking fourteen stations in the Strait (Sts. 542–55), and continuing the voyage from the South Shetlands to Adelaide Island (Sts. 556–60), and westwards along the ice-edge of the Bellingshausen Sea to about 100° W, 70° S, and back to Adelaide Island (Sts. 561–82). A line of stations was worked north-westwards from Adelaide Island (Sts. 583–92) and a number of other stations off Adelaide Island, the Biscoe Islands, the South Shetlands, and the South Orkneys (Sts. 593–617, January–February)—a period largely occupied also with survey work. The voyage was continued to the South Sandwich Islands (Sts. 618–29), westward towards the Falkland Islands (St. 631), south again to the South Orkneys (Sts. 633–6) and Bransfield Strait (Sts. 637–44), north towards Staten Island (Sts. 646–9), and back to South Georgia at the end of March (Sts. 655–9). In the meantime the 'William Scoresby' returned to South Georgia in January and made a cruise south-eastwards past the South Sandwich Islands, and southwards to the ice-edge in the eastern part of the Weddell Sea, making the return journey on much the same route (WS 534–65, January–

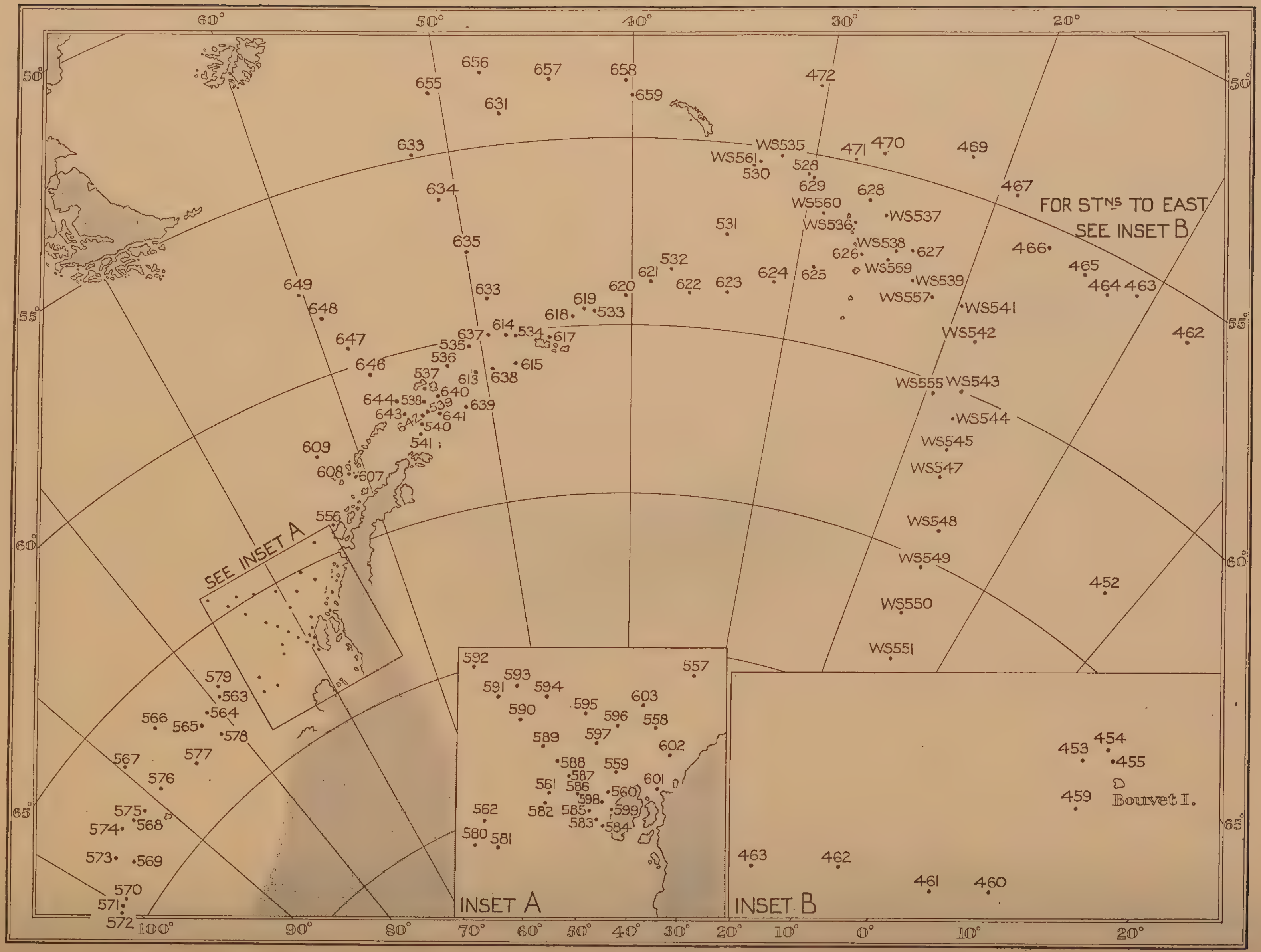

Fig. 14. Stations in the Scotia, Weddell and Bellingshausen Seas, etc., 1930–1.

February). In March she repeated a line of the November survey off South Georgia (WS 567–75) and the season's work was over.

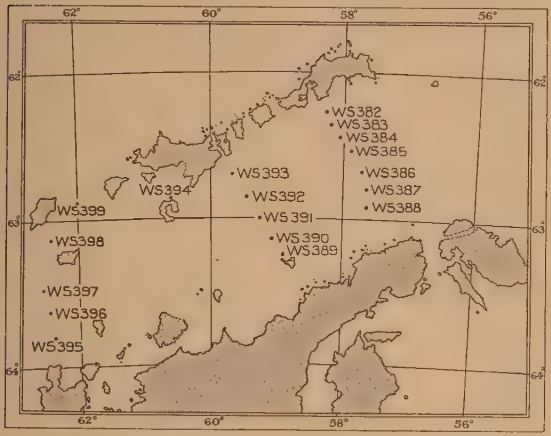

Fig. 15. Stations in Bransfield Strait, 1928–9.

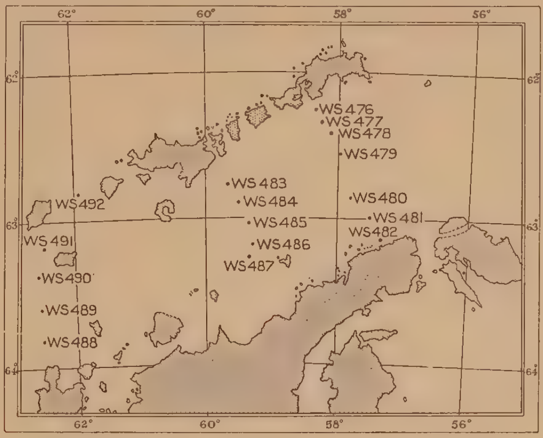

Fig. 16. Stations in Bransfield Strait, 1929–30.

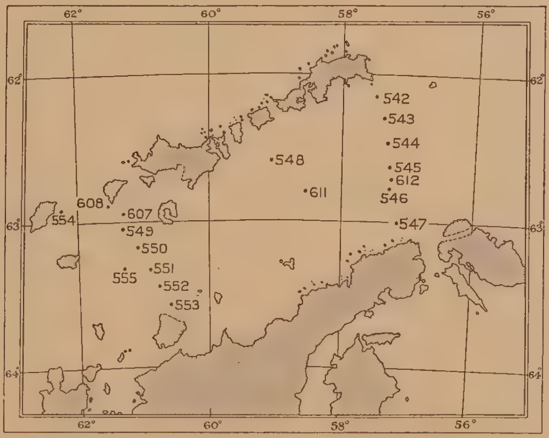

Fig. 17. Stations in Bransfield Strait, 1930–1.

By the time the present paper was ready for publication the 'Discovery II' had returned from a second commission, and a large collection of new N 100 B samples was available, but it was thought desirable to publish some results of the four previous seasons' work to avoid the delay which would be entailed if the new material was incorporated with it.

THE ANTARCTIC CONVERGENCE

The Antarctic convergence, which divides the Antarctic from the sub-Antarctic surface waters, is an important faunistic boundary. In the period 1927–31 a number of lines of stations crossed this convergence, and it is necessary first to determine which of these stations lie in Antarctic and which in sub-Antarctic water. The Antarctic convergence can be located by a sudden change in surface temperature and is usually found at the point at which the coldest part of the Antarctic water sinks below the level of 200 m. (see Deacon, 1933, p. 192). Applying these criteria to the data given in the Station Lists (*Discovery Reports*, vols. III and IV) the following can be quoted as the stations nearest the convergence in each line of observations made across it. The position of the convergence is shown by an arrow: sub-Antarctic stations are above the arrows and Antarctic stations below them.

1927–28

	WS 139	Cold layer at 750 m.
→		
	WS 140	Cold layer at 200 m.
	WS 205	Cold layer indistinct.
→		
	WS 204	Cold layer at 200 m.

1928–29

	WS 253	Cold layer at 750 m.
→		
	WS 254	Cold layer at 100 m.
	WS 317	Cold layer indistinct.
→		
	WS 316	Cold layer at 80 m.
	WS 405	Cold layer indistinct.
→		
	WS 404	Cold layer at 150 m.
	WS 412	No temperature records.
→	WS 413	No temperature records.
	WS 414	No temperature records.
	WS 431	Faint minimum at 600 m.
→	WS 430	Faint minimum at 400 m.
	WS 429	Cold layer at 200 m.
	WS 437	Cold layer indistinct.
? →	WS 436	No temperature records.
	WS 435	Cold layer at 150 m.

1929–30

	WS 467	No temperature records.
→	WS 466	No temperature records.
	WS 465	No temperature records.
	WS 468	Cold layer indistinct.
→	WS 469	Cold layer at 200–300 m.
	WS 470	Cold layer at 150 m.
	St. 385	Cold layer indistinct.
→		
	St. 384	Cold layer at 200 m.
	St. 389	Surface temperature 4·35° C.
→	St. 390	Surface temperature 4·85° C.
	St. 392	Surface temperature 3·90° C.
	WS 520	Faint minimum at 600 m.
→		
	WS 521	Cold layer at 200 m.
	WS 530	Cold layer indistinct.
→		
	WS 529	Cold layer at 150 m.
	St. 396	Surface temperature 7·45° C.
→		
	St. 394	Surface temperature 4·15° C.

1930–1

	St. 451	Cold layer indistinct.
	St. 452	Cold layer at 100–150 m.
→	St. 633	Surface temperature 5·14° C.
	St. 632	Surface temperature 4·85° C.
→	St. 631	Surface temperature 5·80° C.
	St. 630	Surface temperature 3·40° C.
	St. 650	Cold layer indistinct.
	St. 649	Faint minimum at 400 m.
→		
	St. 648	Cold layer at 80 m.
	St. 655	Faint minimum at 800 m.
	St. 656	Cold layer at 300 m.
→		
	St. 657	Cold layer at 150 m.

Where a pair of stations is shown in the above list the convergence lies between them. Thus at WS 254 the cold layer lies at 100 m., while at WS 253 it lies at 750 m.: WS 253 is therefore in sub-Antarctic and WS 254 in Antarctic water. At WS 404 the cold layer is at 150 m., while at WS 405 it has become obscured through sinking and mixing with deeper water. This indicates that WS 405 is well on the north side of the convergence. At such stations the cold layer can be detected only as an irregularity in a curve showing the rate of decrease of temperature as the depth increases. WS 469 lies just about on the convergence itself. At some stations no temperatures, or only surface temperatures, are given. Thus WS 413, 466 and St. 390 probably lie very near the convergence. Sts. 630–3 lie near an eddy, which is roughly indicated by the bend of the convergence in Fig. 1. From its surface temperature it is evident that St. 630 is in Antarctic water. Sts. 631 and 633 are probably very close to the convergence, and St. 632 in Antarctic water. Sts. 391 and 395, at which the N 100 B was not fished, are omitted from the list.

A full account of the differences and resemblances which exist between the plankton of the surface waters of the Antarctic and sub-Antarctic Zones would be a large subject and will probably be dealt with in subsequent publications. I will give here only a brief indication of the effect of the convergence as a faunistic barrier, and for this purpose have examined the N 100 B analyses for twenty stations lying between 100 and 200 miles north of the convergence. The Copepoda have been identified in only eight of these analyses, but they will serve for a purely qualitative comparison.

Antarctic species occurring north of the convergence can be divided into the following:

Normal inhabitants of sub-Antarctic water

Calanus simillimus. Occurs at five out of eight stations, sometimes in moderate numbers.

Rhincalanus gigas. Occurs at seven out of eight stations, and is generally the most numerous copepod.

Pleuromamma robusta. Appears to occur at four out of eight stations, but its specific identity at these sub-Antarctic stations has not been checked with absolute certainty.

Eucalanus sp. Occurs at four out of eight stations, usually in small numbers.

Parathemisto gaudichaudi. Occurs at seventeen out of twenty stations. Barnard (1932, pp. 6–19) records this species in surface waters at various stations in comparatively low latitudes.

Primno macropa. Occurs at nine out of twenty stations, a high proportion for this species. Occurrence in sub-Antarctic waters confirmed by Barnard.

Vibilia antarctica. Occurs at four out of twenty stations—a sufficiently high proportion. Recorded by Barnard in two sub-Antarctic surface hauls. It is evidently less common than *Primno* in these latitudes.

Euphausia vallentini. Recorded in only eleven out of the twenty stations, but occurs sometimes in large numbers and is actually a typical sub-Antarctic species which only occasionally strays into the Antarctic.

Cleodora sulcata. Recorded at four of the twenty stations. No doubt less common in sub-Antarctic than in Antarctic water.

Limacina balea. Occurs at eleven out of the twenty stations. Massy (1932) gives its distribution as the "temperate zones between Arctic and Antarctic and circumtropical zone".

Spongiobranchaea australis. Occurs at five out of the twenty stations. This is a fairly high proportion.

Dimophyes arctica. This species occurs in large numbers only in the coldest Antarctic water. However, it is recorded at one of our twenty stations, and I am informed by Capt. Totton that it occurs quite commonly at various depths throughout the Atlantic, and there are instances of its occurrence in tropical and sub-tropical surface waters. The latter record can hardly be attributed to accidental straying into warmer waters.

Only juvenile stages apparently common in sub-Antarctic water

Calanus propinquus. At least one of the eight stations has an example of this species and at six of the eight there are varying numbers of young copepods which appear to be *C. propinquus*.

Species probably belonging only to the Antarctic water, but which occasionally stray into sub-Antarctic water

Calanus acutus. Several occurred at one of the eight stations, but it is probably rare everywhere north of the convergence.

Metridia gerlachei. One specimen was recorded at two of the eight stations, but it is really typical of the colder Antarctic water.

Euphausia frigida. Two doubtful records in the twenty stations. This species is not usually taken anywhere to the north of the convergence.

Euphausia triacantha. One example recorded in the twenty stations. Not uncommon in stations only a short distance north of the convergence.

Limacina helicina. Recorded at two of the twenty stations, but like *Metridia* is found mostly in the colder Antarctic water.

Salpa fusiformis f. *aspera*. Occurs at one of the twenty stations. It is said to have a very wide distribution (Ihle, 1912), but it seems commonest in Antarctic water.

Among the organisms of which only the genus is identified, *Tomopteris*, *Pareuchaeta*, *Candacia* and *Thysanoessa* commonly occur in sub-Antarctic water, and *Cyllopus* and *Euchirella* occur once each. The Antarctic species which do not occur at these stations are *Diphyes antarctica*, *Pyrostephos vanhöffeni*, *Vanadis antarctica*, *Auricularia antarctica*, *Haloptilus ocellatus*, *Eusirus antarcticus*, *Euphausia superba*, *E. crystallorophias*, *Clione antarctica*, *Solmundella* sp., *Antarctomysis* sp., and *Haloptilus* sp.

These results may need some revision if a larger body of material is taken into consideration, but they are enough to show that some of the common Antarctic species are also normal inhabitants of sub-Antarctic surface waters, while others are sufficiently rare in the latter zone to be regarded as intruders if they are found there.

DIURNAL VARIATIONS

During the daytime some species sink to a depth which is beyond the reach of the net, while others do not. Therefore, in order to trace the distribution of the macroplankton we must have some idea of the hours between which a haul will be indicative of the presence or absence of each species. The following section of this paper is, however, confined to the study of diurnal variations *as they affect the catches in the N 100 B*, and should not be taken as an attempt to investigate the vertical migrations of the different species. Diurnal variation is, so to speak, an adventitious phenomenon which is caused by vertical migrations, and the proper study of the latter should depend mainly upon hauls taken at different depths with closing nets. Hardy and Gunther (1934) have studied in this way the vertical migrations of certain Antarctic species, and reference to their results is made on p. 96.

The majority of the N 100 B samples from Antarctic water have been collected indiscriminately at all hours of the day and night, so that an estimation of the diurnal variations could be worked out for each species if a comparison were made of the average number per haul for various times of day. The accuracy of the results of this calculation might be disturbed by three factors: (i) the irregularity of distribution of the plankton, (ii) the possible effect of the difference in the period of darkness in different latitudes, and (iii) the varying depths from which the net is fished. These difficulties cannot altogether be disposed of, but the quantity of data is sufficient to swamp any serious error arising from distribution, and we can afford to restrict the estimation almost entirely to samples taken between 52 and 60° S. This will include the great majority of stations without too great a range of latitude. Errors arising from the different depths at which the net begins its oblique passage towards the surface will also be largely discounted through the abundant data. The calculation will of course be rough, but sufficient for our immediate purpose.

It must be remembered that the diurnal variations revealed by this method are those which result only from the more extensive vertical migrations. There may, for instance, be certain species having a well-defined vertical migration within the limits of the Antarctic surface layer, and these might seem here to show little or no diurnal variation.

Of previous work on vertical migrations that of Russell (1925–31) is the most important, but this was done on a much finer scale in the shallow water of the English Channel. It revealed movements of a kind which could not be detected in the N 100 B and took into account various subsidiary factors which must be ignored here.

In working out the variations for each species I have omitted the following stations: (i) All those south of latitude 60° S. (ii) Those in which it was not possible to make a reliable estimate of the numbers of the species in question (such as samples which were

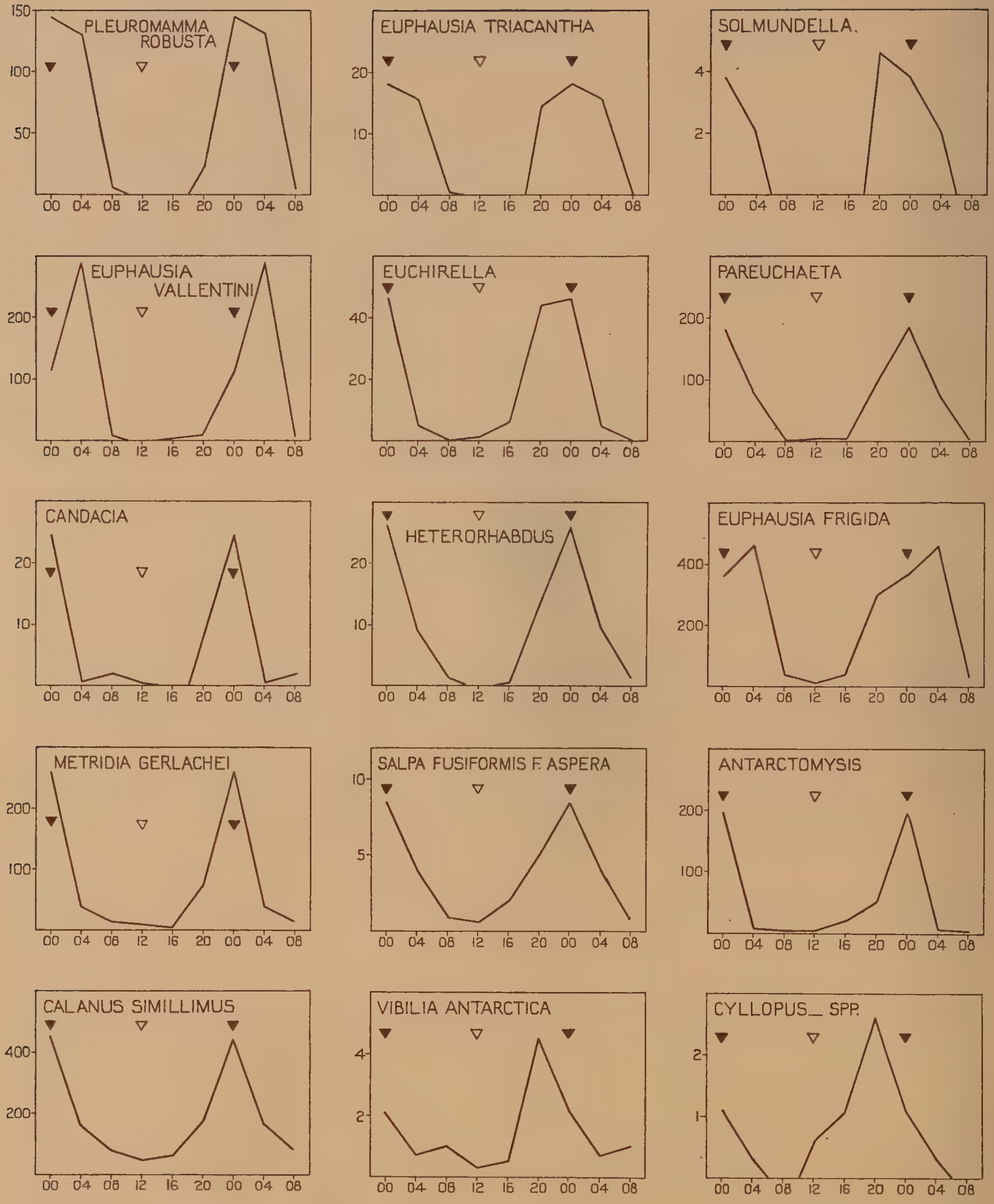

Fig. 18. Diurnal variations of macroplankton species. The curves show the average number per haul at four-hour intervals. Midnight and midday are accentuated by black and white triangles respectively. The species are arranged roughly in order of the magnitude of their diurnal variation (see Table I, p. 95).

swamped with a shoal of *Euphausia superba* or *Salpa*). (iii) Those in an area which was evidently altogether devoid of the species in question. (iv) Those in an area in which the only samples were from a series of daily stations all taken at the same time of day.

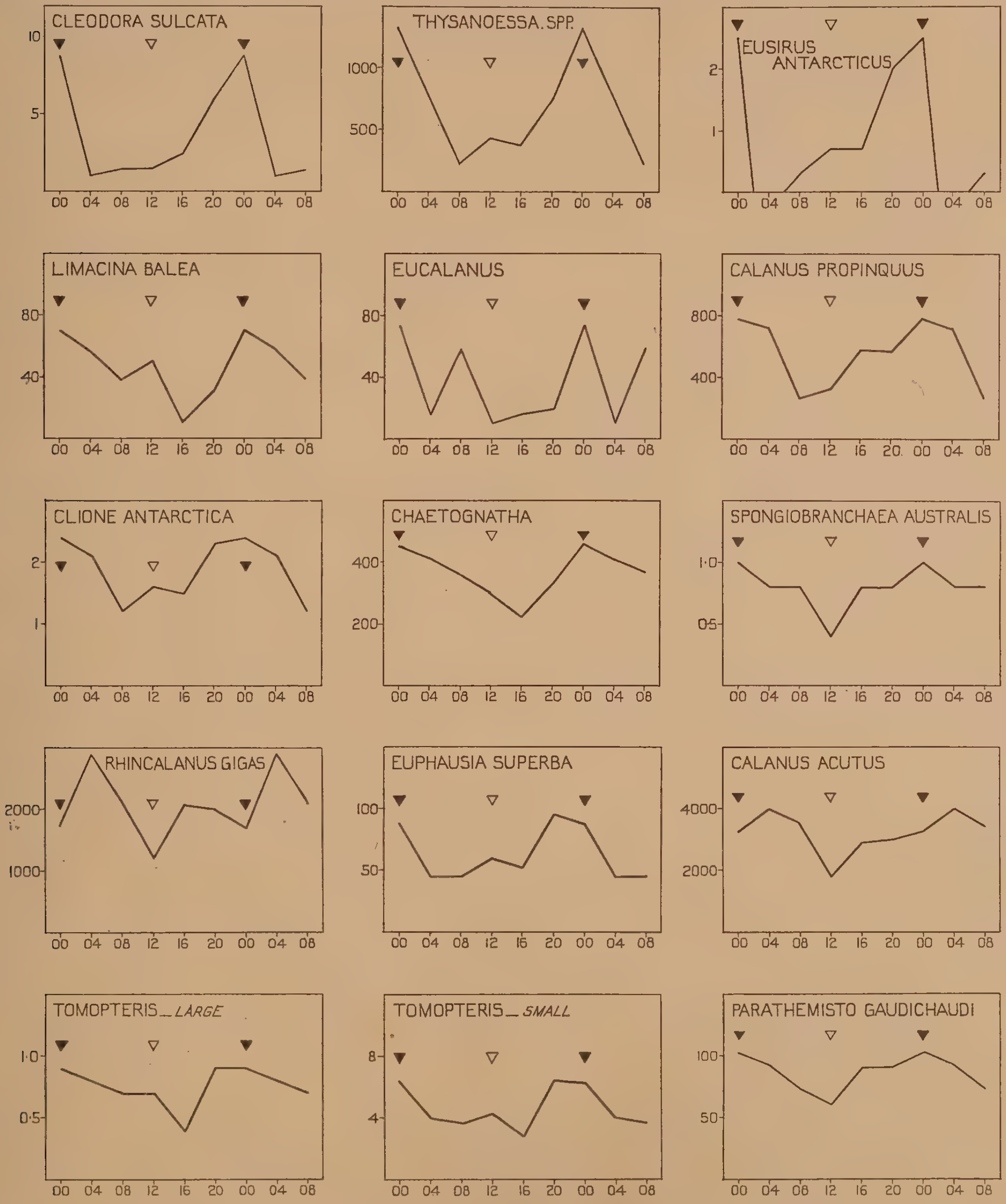

Fig. 19. Diurnal variations of macroplankton species (see legend to Fig. 18).

Figs. 18, 19 and 20 show the variations for each species. With the available data the average per haul for periods of one hour, or even two hours, gives figures which are a little too erratic. Four-hour periods, however, give more regular results, and have therefore been adopted in the construction of the curves. These figures are given in Table I, p. 95.

The following pages contain notes on the variation of individual species. It has already been mentioned that during a cruise of the 'Discovery II' a 24-hour station, 461, was worked south of Bouvet Island. At this station seven flights, each of six oblique closing 1 m. nets, were towed every four hours at a series of depths down to about 700 m., and I have made a preliminary analysis of the samples. Although the present paper is really concerned with the routine N 100 B samples, it will perhaps be permissible to refer here and there to the results of St. 461 in so far as they apply to the results shown in the table on p. 95. There is also a line of stations (618–25) at which the net was hauled twice a day at about 10 a.m. and 10 p.m. through a region of uniform plankton, and these constitute a useful piece of independent evidence.

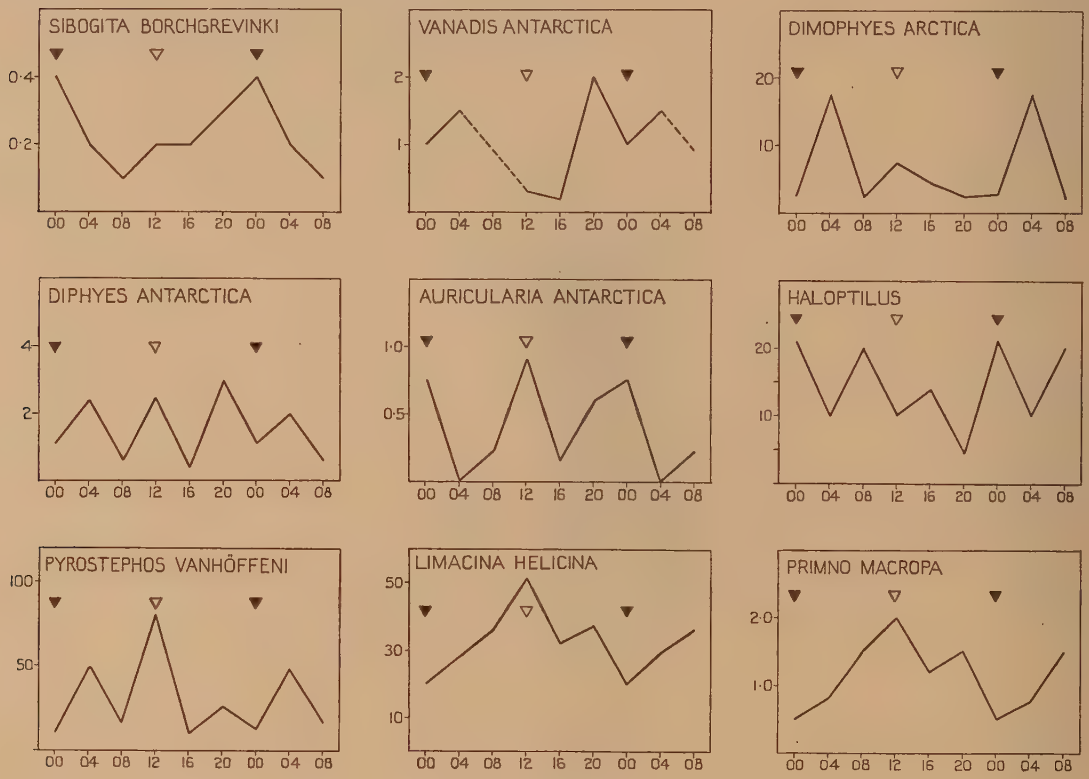

Fig. 20. Diurnal variations of macroplankton species (see legend to Fig. 18).

Diphyes antarctica (Fig. 20). The material is limited, but it is enough to show that there is no significant variation. Specimens taken at St. 461 show no apparent vertical migration.

Dimophyes arctica (Fig. 20). The curve for this species is unreliable, not so much because the species is uncommon north of 60° S as because it occurs in sharply fluctuating numbers. Thus the peak at 0400 is due to only two stations at which the species appeared in larger numbers than usual. The instances of its occurrence are quite evenly distributed throughout the day, and it is very improbable that there is any real variation. The distribution of this species at St. 461 strongly suggests that there is no variation.

Pyrostephos vanhöffeni (Fig. 20). The curve is actually made out for the numbers of nectophores, and not the individual colonies. It is a patchy species and the peak at midday is due to only one station, at which an abnormal number occurred. The actual occurrences are equally distributed through the 24 hours, and the species can be regarded as having no significant diurnal variation.

Sibogita borchgrevinki (Fig. 20). Only fifteen specimens were taken north of 60° S, so that a reliable curve cannot be drawn. The fifteen were spread equally through the day and night, but the stations at which it was counted as absent were mostly day stations. Several specimens occur at St. 461, but there is no sign of any vertical migration.

Solmundella sp. (Fig. 18). This is not a very common form, but in contrast to the four preceding species, it has a very clear diurnal variation, no specimens having been taken in the daytime between 0500 and 1859, except in high latitudes. It is not represented at St. 461.

Tomopteris sp. (large) (Fig. 19). There is a slight suggestion of variation, about equivalent to that of *Calanus acutus*, but it is not of much significance. No conclusive results are to be found in St. 461 or in Sts. 618–25.

Tomopteris sp. (small) (Fig. 19). Similar to the large *Tomopteris*. All these curves which show a slight variation have peaks which might be regarded as accidental, were they not all at or near midnight.

Vanadis antarctica (Fig. 20). As in the case of *Sibogita* we have insufficient material for a trustworthy curve. The genus is recorded at only thirteen stations north of 60° S. They are spread throughout the day, so that there is not likely to be any very significant variation. On the whole slightly more specimens were taken at night.

Auricularia antarctica (Fig. 20). Again there are very few specimens north of 60° S, but these show no sign of any variation; nor do those from farther south. It must perhaps still be regarded as a doubtful species, but any important diurnal variation is very unlikely.

Calanus acutus (Fig. 19). The averages of a large number of hauls and vast numbers of specimens show a slight diurnal variation. The species, however, is taken at all hours, and some of the biggest catches have been in the daytime. There is perhaps a faint suggestion of a tendency towards vertical migration at St. 461, but there is no sign of any variation at Sts. 168–25, and it may for the present be regarded as a species without significant diurnal variation.

Calanus propinquus (Fig. 19). The exact amount of diurnal variation cannot properly be estimated without a very large body of data. There is evidently rather more than in *C. acutus*, but the largest hauls of this species also can be taken in daytime as well as at night. St. 461 gives no definite indication, but Sts. 618–25 confirm the existence of some variation.

Calanus simillimus (Fig. 18). The curve shows a clear variation. The species has been caught at nearly as many day stations as night stations, but the night catches are larger. It is not represented at St. 461.

Rhincalanus gigas (Fig. 19). This species again can be taken in the greatest abundance during the day, but on balance there seems to be some sort of variation. St. 461 and Sts. 618–25, however, do not suggest any definite migration or variation.

Pleuromamma robusta (Fig. 18). Of all species found in the Antarctic surface water, this has on the whole the most pronounced diurnal variation. Examples occurred in only three hauls out of 196 between 0600 and 1959. The vertical migration is shown very clearly at St. 461. It appears to sink below 600 m. during the day, and rises to within reach of the N 100 B only within a few hours of midnight.

Metridia gerlachei (Fig. 18). Here again there is a strongly marked migration, but specimens have occasionally been taken in daytime. At St. 461 there was a wide range of vertical distribution, but the vertical migration was not well defined.

Haloptilus ocellatus. This species occurred only once north of 60° S. Specimens from farther south show no sign of diurnal variation, and St. 461 suggests that there is no vertical migration.

Haloptilus sp. (Fig. 20). Occurrences are spread equally through the 24 hours, and the figures from St. 461 suggest no vertical migration.

Pareuchaeta sp. (Fig. 18). The diurnal variations are very clearly defined, and examples are rarely taken during the hours of daylight. It is evident that this genus lives at a considerable depth and comes within reach of the net only at night. This supposition is confirmed by the catches at St. 461.

Heterorhabdus sp. (Fig. 18). The genus is uncommon, but great variation obviously takes place. St. 461 shows that it lives at a deep level but the series of hauls does not bring out the vertical migration very clearly.

Eucalanus sp. (Fig. 19). The material again is limited and the numbers in which the species occurs are variable. There is evidently a certain amount of variation, but there have been nearly as many occurrences in daytime as at night, and it is difficult to know what would result from a larger body of data. A vigorous vertical migration is improbable.

Euchirella sp. (Fig. 18). There is little material, but there is evidently a marked variation. St. 461 shows a considerable amount of vertical migration.

Candacia sp. (Fig. 18). This is another uncommon organism, but there is no question that it is normally beyond the reach of the net during daytime. The few specimens occurring at St. 461 were taken in the deepest nets.

Parathemisto gaudichaudi (Fig. 19). There is only a slight variation, roughly equivalent to that of *Calanus acutus*. Curiously enough Sts. 618–25 suggest quite a marked diurnal variation. At successive stations the catches were as follows: 21, 4, 260, 7, 19, 8, 68, 1. The alternate large catches were those from the night stations. It was absent from St. 461 except for some doubtful juvenile stages. At all events this species has actually been caught in both large and small numbers almost as often during the day as during the night.

Primno macropa (Fig. 20). The behaviour of this species is most remarkable. From the figures for diurnal variation it seems impossible to avoid the conclusion that it rises to the surface in the daytime and sinks at night, for although the species is of common occurrence in small numbers, none is recorded between 2200 and 0159 except for a single batch of twenty. On the other hand there is a clear maximum about midday. Few were caught at St. 461, but there is no sign of such a reversed migration. Diurnal variation is not of course necessarily proof of a corresponding vertical migration. It is conceivable, for instance, that a species like this might become localized at night into small shoals which are missed by the net.

Vibilia antarctica (Fig. 18). The material is not really adequate and the numbers are patchy. However, there is a most distinct variation. The fact that the peak comes rather before midnight is due to only two or three samples which were abnormally large.

Eusirus antarcticus (Fig. 19). A very doubtful species. Among those occurring south of 60° S there is no evidence of any diurnal variation. Those occurring north of 60° S suggest a sharp variation, but there are so few of them that the apparent maximum around midnight may be quite accidental.

Cyllopus sp. (Fig. 18). There is not very much to go on, but there seems to be a marked variation. As in *Vibilia* the peak comes before midnight, but with the available material we cannot be sure whether this is accidental or whether it represents the actual state of affairs.

Antarctomysis sp. (Fig. 18). There is a pronounced diurnal variation, though the genus has been taken practically as often during the day as at night. This is perhaps connected in some way with the neritic distribution of this genus.

Euphausia superba (Fig. 19). This is a difficult species to deal with owing to its extreme patchiness and tendency to form shoals. Many of the big shoals have been seen at the surface during both the night and the day, but the deeper shoals and the more scattered individuals might undertake vertical migrations. For the estimation of the average per haul at different hours, samples containing over 1000 *E. superba* have been disregarded. This should eliminate the disturbing influence of heavy shoal catches and give some idea of the general behaviour of the species. The resulting curve suggests only a minor degree of diurnal variation. At St. 461 the majority seemed to remain near the surface, while those living at greater depths gave some signs of moving up and down. At Sts. 618–25 there was quite a marked diurnal variation. The explanation would seem to be that while a section of the population of this species undergoes some vertical migration, the greater part remains at the same level, especially perhaps when forming shoals.

Euphausia frigida (Fig. 18). The variation is strongly defined, but fair-sized catches appear now and then during the day and the period of abundance at night is a little more extended than in such organisms as *Pareuchaeta* and *Metridia*. St. 461 suggests a vigorous migration, and the diurnal variations are clearly shown at Sts. 618–25.

Euphausia crystallorophias. This is a neritic species of which few examples have been taken, and none north of 60° S. The few that occur south of 60° S give some suggestion of diurnal variation, and since most of the other species of *Euphausia* undertake vertical migrations, it is probable that *E. crystallorophias* does so too.

Euphausia triacantha (Fig. 18). Here the variation is almost as sharply defined as in *Pleuromamma*. Examples occurred in only three out of 127 hauls between 0600 and 1759.

At St. 461 very few specimens were taken and the vertical migration is not well defined, but it is clear that this species lives at a considerable depth.

Euphausia vallentini (Fig. 18). Since this really belongs to the sub-Antarctic water there is not much material to go on. All that can be said is that there is a very definite variation which seems slightly more marked than that of *E. frigida*.

Thysanoessa spp. (Fig. 19). There is a clear diurnal variation, but it is not nearly so marked as in *Euphausia triacantha* and *E. frigida*. Examples are taken just as often in the middle of the day as at night, but the night hauls are on the average larger. At St. 461 *Thysanoessa* seems much scarcer in daytime, at all depths down to 600 m., than at night. The variations at Sts. 618–25 are of the same order as those shown in the curve.

Cleodora sulcata (Fig. 19). There is evidently a distinct variation. However, the species occurs quite commonly in small or moderate numbers during the day. Three large catches, which were evidently abnormal, have been disregarded in the construction of the curve. There is evidence of vertical migration at St. 461, but no data from Sts. 618–25.

Limacina helicina (Fig. 20). This species seems to be commoner at midday than at midnight, but there is not a great amount of material and it is possible that the peak at midday is accidental. The actual occurrences are distributed through the 24 hours as evenly as could be expected. There is no definite evidence from St. 461 or Sts. 618–25.

Limacina balea (Fig. 19). Like *Euphausia superba*, this species is difficult to place on account of its patchy distribution and tendency to form shoals. The curve is constructed from samples containing less than 1000. This represents the great majority of hauls and shows quite a modest variation, but it is noteworthy that the catches of 1000 to 6000 all took place at night, while two or three catches of 20,000 to 160,000 seemed to bear no particular relation to the time of day. There is no definite evidence from St. 461 or Sts. 618–25.

Spongiobranchaea australis (Fig. 19). Here the rather limited material suggests that there is a slight variation, but the numbers of catches in which the species occurs are fairly equal through the day. There are no examples at Sts. 618–25, and too few at St. 461 to justify any conclusions.

Clione antarctica (Fig. 19). The figures suggest a slight variation of the same order as that of *Calanus propinquus*. There are few specimens but no indication of vertical migration at St. 461.

Salpa fusiformis f. *aspera* (Fig. 18). This is another of those species of which the vast majority of specimens actually caught have been from a limited number of swarms. If shoal catches are included in the calculation of the mean values for the different times of day they produce an unfair distortion of the curve of variation. All samples of 100 or more Salps have therefore been disregarded here, and the resulting curve shows a regular and well-marked variation. If all samples of twenty or more Salps are also disregarded, the shape of the curve is not much affected. There were not enough specimens at St. 461 to provide additional evidence, and none occurred at Sts. 618–25.

Chaetognatha (Fig. 19). The variations of the group as a whole are equivalent to those of *Calanus propinquus*. Large catches are liable to be taken at all times of the day. St. 461 gives inconclusive results, but there is a distinct variation at Sts. 618–25.

Table I. *Mean diurnal variations*

	Average numbers per haul for 4-hour periods						Hours between which hauls are regarded as valid
	0000 (2200–0159)	0400 (0200–0559)	0800 (0600–0959)	1200 (1000–1359)	1600 (1400–1759)	2000 (1800–2159)	
Pleuromamma robusta	145	130	6	0	0	23	2100–0259
Euphausia triacantha	17·9	15·5	0·3	0	0	14·7	2000–0359
Solmundella sp.	3·8	2·0	0	0	0	4·6	2000–0359
Euphausia vallentini	110	290	7·3	0	0·2	11·1	2000–0359
Euchirella sp.	46·5	5·2	0·1	1·2	6·0	44·7	2100–0259
Pareuchaeta sp.	183	75	2	4	5	97	2000–0359
Candacia sp.	24·3	0·4	1·8	0·1	0	8·4	2100–0259
Heterorhabdus sp.	25·9	9·2	1·2	0	0·2	13·3	2000–0359
Euphausia frigida	366	458	33	8	39	302	1800–0559
Metridia gerlachei	258	39	15	11	6	74	2000–0359
Salpa fusiformis f. *aspera*	8·4	4·0	0·9	0·6	1·0	4·9	2000–0359
Antarctomysis sp.	196	6·2	2·4	2·1	19·6	50	2000–0359
Calanus simillimus	446	161	82	53	58	166	1800–0559
Vibilia antarctica	2·1	0·7	1·0	0·3	0·5	4·5	1900–0459
Cyllopus spp.	1·1	0·3	0·0	0·6	1·1	2·6	1900–0459
Cleodora sulcata	8·7	1·0	1·4	1·4	2·4	5·8	1900–0459
Thysanoessa spp.	1318	779	221	435	385	729	1800–0559
Eusirus antarcticus	2·5	0·0	0·3	0·7	0·7	2·0	1800–0559
Euphausia crystallorophias	3·7	1·2	1·2	1·8	4·1	0	All hours
Limacina balea	70	57	38	51	11	30	1700–0659
Eucalanus sp.	73·2	15·7	58·0	10·2	16·4	18·9	1700–0659
Calanus propinquus	779	713	261	331	571	559	1700–0659
Clione antarctica	2·4	2·1	1·2	1·6	1·5	2·3	1700–0659
Chaetognatha	451	408	370	301	220	333	1700–0659
Spongiobranchaea australis	1·0	0·8	0·8	0·4	0·8	0·8	1600–0759
Rhincalanus gigas	1733	2898	2086	1208	2030	2006	1600–0759
Euphausia superba	88	46	46	61	53	96	All hours
Calanus acutus	3250	3969	3453	1849	2890	3021	„
Tomopteris sp. (large)	0·9	0·8	0·7	0·7	0·4	0·9	„
Tomopteris sp. (small)	6·3	4·0	3·7	4·2	2·9	6·4	„
Parathemisto gaudichaudi	103	92	73	61	90	92	„
Sibogita borchgrevinki	0·4	0·2	0·1	0·2	0·2	0·3	„
Vanadis antarctica	1·0	1·5	—	0·3	0·2	2·0	„
Dimophyes arctica	2·6	17·7	2·2	7·5	4·4	2·5	„
Diphyes antarctica	1·1	2·2	0·6	2·5	0·4	3·0	„
Auricularia antarctica	1·0	0	0·3	1·2	0·2	0·8	„
Haloptilus sp.	22·2	10·0	20·0	11·0	14·0	4·4	„
Haloptilus ocellatus	48	—	—	128	120	164	„
Pyrostephos vanhöffeni	11·2	48·4	16·1	80·3	10·5	27·1	„
Limacina helicina	20·5	28·7	36·3	51·3	31·9	37·2	„
Primno macropa	0·5	0·8	1·5	2·0	1·2	1·5	0400–1959

Throughout this paper hours are expressed according to the 24-hour notation. Bracketed figures at the head of the columns represent the range in time of the observations, while the mean of the 4-hour period, which has been used in the construction of Figs. 18–20, is placed above.

Among the various species there is a complete gradation from those which are plentiful at night and completely vanish from the catches in daytime, to those which show no diurnal variation at all, or which even increase during the day and diminish at night. In Table I on p. 95 the various units are arranged roughly in order of the magnitude of their diurnal variations, and the figures in the first six columns are the average numbers per haul, upon which the curves in Figs. 18–20 are based. Thus *Pleuromamma robusta* averages 145 per haul between the hours of 2200 and 0159, and sinks beyond the reach of the net during the daytime or at least the afternoon. On the other hand such species as *Pyrostephos vanhöffeni* show no clear indication of any diurnal variation and in *Primno macropa* the variation seems actually to be reversed.

It is now clear that observations taken in the middle of the day must be disregarded in any consideration of the distribution of the more migratory species, and it must be decided exactly which hauls can be admitted as an indication of the numbers of each species present. Without a fuller knowledge of the details of vertical migration, as distinct from diurnal variation, the best that can be done is to select, for each variable species, a period of hours before and after midnight which will be appropriate to the diurnal variations of that species. For *Pleuromamma*, for instance, we might allow as valid only the hauls between 9 p.m. and 3 a.m. (2100–0259), while we need not disregard any hauls for such organisms as *Pyrostephos*. Column 7 in Table I shows the periods during which a haul is regarded, for the purposes of the present paper, as an indication of the presence or absence of a species. Those listed in the table below *Rhincalanus* are regarded as having insufficient diurnal variation to merit the exclusion of any of the daytime hauls. It occasionally happens that a species, which on the average is plentiful only at night, is caught in unexpectedly large numbers during the day. If such a catch were comparable to the average haul taken at night about the same time and in the same locality, it may be taken into consideration in the distribution of the species.

Hardy and Gunther (1934) have discussed the vertical migrations of certain species which are included in Table I and conclude that a more or less marked migration is shown by the following species: *Calanus propinquus*, *C. simillimus*, *Metridia gerlachei*, *Pareuchaeta antarctica*, *Parathemisto gaudichaudi*, *Vibilia antarctica*, *Cyllopus* spp., *Euphausia superba*, *E. frigida*, *E. triacantha*, *Thysanoessa* spp., *Limacina helicina*, and *Salpa fusiformis*. Table I shows that all except four of these species also show a clear diurnal variation, and it is therefore mainly in agreement with Hardy and Gunther's results. The exceptions are *Calanus propinquus*, *Parathemisto gaudichaudi*, *Euphausia superba*, and *Limacina helicina*. The explanation of the fact that they show little diurnal variation in the catches of the N 100 B is probably to be explained on the grounds that they inhabit mainly the upper layers, and that their vertical migrations do not take the bulk of them beyond the reach of the net at night. Hardy and Gunther find little or no migration in *Calanus acutus* and *Rhincalanus gigas*, and this also is in agreement with the results expressed in Table I.

RELATIVE ABUNDANCE AND DISTRIBUTION OF INDIVIDUAL SPECIES

In different parts of the Atlantic sector of the Antarctic the plankton varies considerably in both abundance and constitution, and to find the actual relative quantities in which the different species exist would be a very difficult matter, even if it was particularly desirable to do so. However, it is necessary to give some indication as to which species are abundant and which species are uncommon, and the following table shows the average per haul (all hauls with the N 100 B in the Antarctic) and the largest single catch for each species. A disproportionately large number of these hauls have been made in the neighbourhood of South Georgia, but this is a region in which, from time to time, representatives of the plankton typical of both the warmer and colder parts of the Antarctic waters are found.

Table II. *Relative abundance of species (expressed to two significant figures)*

Species	Average number per haul	Largest catch	Species	Average number per haul	Largest catch
			Abundant		
Calanus acutus	1900·00	67,000	*Thysanoessa* spp.	420·00	15,000
Rhincalanus gigas	1200·00	20,000	*Calanus propinquus*	390·00	28,000
*Euphausia superba**	1000·00	190,000	Chaetognatha	260·00	6,300
*Limacina balea**	440·00	160,000			
			Numerous		
Euphausia frigida	140·00	5,800	*Pareuchaeta* sp.	52·00	5,500
Parathemisto gaudichaudi	110·00	3,000	*Pleuromamma robusta*	40·00	6,200
Metridia gerlachei	87·00	6,100	*Salpa fusiformis* f. *aspera**	29·00	6,700
Calanus simillimus	86·00	41,000	*Limacina helicina*	21·00	960
			Moderate		
Antarctomysis sp.	9·80	1,800	*Euchirella* sp.	3·20	510
Pyrostephos vanhöffeni	9·00	1,200	*Cleodora sulcata*	3·10	550
Euphausia vallentini	6·60	1,800	*Haloptilus* sp.	2·40	100
Eucalanus sp.	5·50	590	*Heterorhabdus* sp.	2·20	260
Haloptilus ocellatus	5·40	520	*Dimophyes arctica*	1·90	180
Euphausia triacantha	4·50	230	*Candacia* sp.	1·60	100
Tomopteris sp. (small)	3·60	100	*Clione antarctica*	1·10	40
			Few		
Vibilia antarctica	0·82	66	*Auricularia antarctica*	0·53	100
Primno macropa	0·77	90	*Spongiobranchaea australis*	0·40	27
Cyllopus spp.	0·60	110	*Solmundella* sp.	0·29	32
Euphausia crystallorophias	0·60	200	*Eusirus antarcticus*	0·15	9
Diphyes antarctica	0·59	23	*Vanadis antarctica*	0·08	3
Tomopteris sp. (large)	0·58	39	*Sibogita borchgrevinki*	0·05	2

* Species of which the majority have occurred in shoals or dense patches.

There are large differences in the uniformity of distribution of these species, and some tend to form shoals, or large or small areas of dense concentration. *Euphausia superba* lives mainly in shoals, and *Limacina balea* and *Salpa fusiformis*, though normally found in small numbers, sometimes occur in exceptionally dense masses which may extend over many square miles. Other species such as *Parathemisto gaudichaudi* and *Calanus simillimus* are found only occasionally in abnormally large numbers, the majority of specimens being taken in hauls of normal size. Other species again seem to have no tendency to form any definite aggregations. This point will be dealt with more fully when each species is separately considered in the following pages.

The N 100 B analyses provide a large body of data on the distribution of the various species, but separate species or groups will be dealt with in detail in subsequent publications, and the distribution of individual species will therefore be considered in the briefest possible manner here. For the same reason, little reference will be made to records of the occurrence of each species in the publications of other expeditions, for if this were done the following notes would need to be greatly enlarged. Mention should be made, however, of one or two papers which deal with certain aspects of the distribution of the macroplankton in these waters. For example, Ruud (1932) discusses in detail the general biology and distribution of the Antarctic Euphausiidae and the connection between *Euphausia superba* and the distribution of whales. Further reference will be made to this paper in a later section. Ottestad (1932) has treated the principal species of Copepoda in a similar way. The substance of these papers does not very much overlap that of the present paper, but, so far as their conclusions have any bearing on it, they are mainly in agreement with the following notes. Rustad (1930) has also published a paper on the identification and development of the southern Euphausiidae, but deals only briefly with their distribution.

Except where otherwise stated, the following notes are derived entirely from the samples on which this paper is based.

Diphyes antarctica. This species is confined to the colder parts of the Antarctic waters, and its northern boundary in the area of the Falkland Islands Dependencies is roughly a line running from the South Shetland Islands to South Georgia. It is usually found in the vicinity of the pack-ice, or in water which has recently been covered by the ice. It seems to be scattered very evenly through the regions which it inhabits, appearing at each station in small numbers, and there have been no indications of any tendency to form shoals or even to occur in definitely larger numbers than usual.

Dimophyes arctica. This species is known to occur at least in sub-Antarctic, as well as Antarctic water, but it is only in the colder waters of the Bellingshausen and Weddell Seas that it appears in any quantities. Here it is quite plentiful, but in warmer regions it is rare. Its distribution is more "patchy" than that of *Diphyes antarctica*, but it cannot be said to occur in shoals.

Pyrostephos vanhöffeni. Recorded from time to time everywhere from the Antarctic convergence to the most southerly stations of the Bellingshausen and Weddell Seas, but it is definitely commoner in the colder than in the warmer parts of the Antarctic water. It is curious that it seems to be absent from the coastal regions of the South

Orkneys, South Shetlands, and the eastern Bellingshausen Sea. Of all the stations in this area, including those in Bransfield Strait, it is recorded only at one or two stations off Adelaide Island. The nectophores appear in very variable numbers in the samples, but this is to be expected, as there are said to be about thirty nectophores to each colony.

Sibogita borchgrevinki. Another species which is confined to the higher latitudes, or at least to the colder waters. Its distribution resembles that of *Diphyes antarctica*, but it appears to reach a little farther north. There is rarely more than a single specimen in one sample, and it is probably distributed evenly through the waters to which it belongs.

Solmundella sp. This is a species which seems to have no particular limits. It occurs in small numbers, but has been found everywhere from the convergence to the cold waters of the Bellingshausen and Weddell Seas. Browne (1910) mentions that *S. mediterranea* is found from the tropics to the Antarctic. There are rarely more than ten in one sample, and I have no record of more than thirty-two.

Tomopteris sp. (large). The large *Tomopteris* also is found everywhere from the convergence to the higher latitudes, but it is distinctly commoner in the colder regions. Like *Pyrostephos*, it seems to be absent from the Bransfield Strait, and the whole of the coastal region from the South Orkneys to the eastern part of the Bellingshausen Sea. It is an evenly distributed species and more than two or three in one sample are rarely found. Only once have more than twelve been taken at a time, and that was an extraordinary catch of thirty-nine at a station off South Georgia. There is an interesting colour variety of *Tomopteris carpenteri*. Ordinary specimens are colourless and transparent, but on certain occasions specimens have been taken which were traversed by two broad bands of bright reddish brown which made the animal strikingly conspicuous. These parti-coloured specimens have been found only in cold water in the neighbourhood of the pack-ice of the Weddell and Bellingshausen Seas.

Tomopteris sp. (small). Like the large *Tomopteris* it is found everywhere in the Antarctic water, but is rather commoner in the colder regions. Unlike the other it is found in the coastal region of the South Orkneys, South Shetlands, and eastern Bellingshausen Sea. Its distribution is sometimes quite uniform and sometimes rather patchy, but I have no record of anything which might be called a shoal.

Vanadis antarctica. Occurs in such small numbers that one cannot draw very certain conclusions as to its distribution. It is almost entirely confined to the cold water of the Weddell and Bellingshausen Seas, especially the latter, but it has also been found at one or two stations near the Antarctic convergence in far warmer water than all the others at which it is recorded. There seems to be no doubt about the identity of these specimens, and their occurrence in such an unusual locality is difficult to account for. There is rarely more than one in a single sample.

Auricularia antarctica. Like *Diphyes antarctica*, this species is strictly confined to the colder regions, but since it occurred at WS 198, WS 474 and St. 594 (see Figs. 10, 12 and 14), its northern limit must be placed a little beyond that of *Diphyes.* It is found in the Bellingshausen Sea, the coastal waters of the South Shetlands and South

Orkneys, and the eastern Weddell Sea. It generally occurs in ones and twos, but catches up to 100 were taken in the eastern Weddell area.

Calanus acutus. Numerically this is the most important species of all. It is distributed throughout the Antarctic surface waters, and there have been catches of 1000 or more everywhere from the convergence to the cold waters of the Bellingshausen and Weddell Seas. The very big catches of 5000 and more have been taken only in the South Georgia and South Sandwich areas, the western Bellingshausen and eastern Weddell Seas. The species is on the whole evenly distributed and there is no tendency to form shoals.

Calanus propinquus. This species also is found everywhere in both the warm and cold parts of the Antarctic surface water, but the largest catches have been taken in the neighbourhood of South Georgia and the South Sandwich Islands. It has no tendency to form shoals, but is perhaps a little more localized than *C. acutus*. For instance at Sts. 360–74 in February and March, 1929–30, it was taken in enormous numbers in the eastern part of the Scotia Sea, and it was by far the most prominent copepod at Sts. 453–72 between Bouvet Island and South Georgia in October 1930–1. Specimens taken near the Antarctic convergence are mostly immature.

Calanus simillimus. Normally confined to the warmer waters of the Antarctic. It has not been taken in the Bellingshausen or Weddell Seas and has not often appeared south of a line running from the north side of the South Shetlands to South Georgia, though around South Georgia it is common enough. In March of the warm 1929–30 season, however, it was taken at Sts. 372–5, west of the South Sandwich Islands. This is normally quite an evenly distributed species, and an abnormally large catch has been taken only once, at WS 184, where over 40,000 were taken at a point close to the south coast of South Georgia. The next largest catches were 5000 at WS 466 just on the north side of the convergence, and 2200 at St. 321 off South Georgia.

Rhincalanus gigas. This species has been caught in large numbers at practically every station in the warmer parts of the Antarctic, and there is little doubt that it is abundantly and evenly distributed in these waters at least during the greater part of the summer. It is also taken in large numbers in the Bellingshausen Sea and in the Weddell Sea water, but here it is not by any means always found in abundance. It occurs in small numbers, though at most stations, in the coastal regions of the South Orkneys, South Shetlands and eastern Bellingshausen Sea. It shows no tendency to form shoals, and cannot be regarded as any more patchy than any of the other more numerous species.

Pleuromamma robusta. This is a warm-water species whose proper habitat in Antarctic water appears to be the outer belt immediately south of the convergence. It is of course also found north of the convergence. It is not uncommon in the Weddell Sea water on both the west and east sides of the South Sandwich Islands, but it has occurred at none of the stations in coastal regions of the South Orkneys and South Shetlands, nor in the Bellingshausen or eastern Weddell Sea. As a rule it is as evenly distributed as most of the other copepods, but a very exceptional catch of over 6000 was taken at St. 452, north of Bouvet Island.

Metridia gerlachei. On the whole a cold-water species. A peculiarity of its distribution is that it is found in much the largest quantities between the South Shetlands and South Orkneys, along the Orkney-Sandwich ridge, and around the South Sandwich Islands. It is one of the very few members of the macroplankton which are found in any considerable numbers in this region. Possibly its method of reproduction is in some way associated with the bottom or with the conditions found in shoal waters. However, it is to be found in varying quantities everywhere from the convergence to the highest latitudes. It is a species which is often distributed evenly over large areas but which sometimes appears suddenly in exceptionally large numbers. It thus has some tendency to form shoals, or at least to appear in local concentrations, and it must be regarded as a patchy species.

Haloptilus ocellatus. This species is confined to the coldest water. It has occurred in moderate numbers (100 to 500 per haul) in the Bellingshausen Sea west of Peter 1st Island and in the eastern Weddell Sea. Occasional specimens are recorded from the Orkney-Shetland region and from the ice-edge near Bouvet Island. There is no evidence to show that its distribution is at all patchy.

Haloptilus sp. Found everywhere from the convergence to the Bellingshausen Sea, but it is not recorded from the Sandwich or eastern Weddell regions, and has appeared only once in the Orkney-Shetland coastal region. However, it is among the rarer Copepoda, and there is not enough material to form the basis of any definite conclusions. It is perhaps commonest in the warmer parts of the Antarctic.

Pareuchaeta sp. This genus also has a wide distribution, but it is commonest in the warmer parts of the Antarctic. Like *Rhincalanus* it pervades the whole of the belt lying immediately south of the convergence and is absent only from hauls taken during the daytime. It appears sometimes in the Bellingshausen and Weddell Seas, and is met with in small numbers in Bransfield Strait, in the coastal waters of the South Orkneys and South Shetlands and in the eastern Bellingshausen Sea.

Heterorhabdus sp. Although this is an uncommon genus it clearly belongs to the warmer parts of the Antarctic water; its distribution seems very similar to that of *Calanus simillimus.*

Eucalanus sp. Also clearly typical of the warmer water, but its occurrence is curiously spasmodic. At one time it may be found at every station of a line, say, from South Georgia to the convergence, while at another time none will be caught along a similar line. On the other hand its distribution does not appear to be in any way patchy.

Euchirella sp. This is one of the rarest of the large Antarctic copepod genera. It has occurred here and there in the warmer water, off South Georgia, in the Bellingshausen and Weddell Seas and in the outflowing Weddell water. We cannot say more than that, as a genus, it is not confined either to the warmer or colder Antarctic water.

Candacia sp. This is another scarce genus, but it has not been found in the colder regions and is commonest close to the convergence. It is clearly a warm-water form.

Parathemisto gaudichaudi. The big catches of this species have all been taken in the warmer parts of the Antarctic water, including the South Georgia whaling grounds. Moderate numbers have occurred in the South Sandwich region and small numbers in the coastal region of the South Orkneys and South Sandwich Islands and in the Bellingshausen Sea. In the warmer waters there are practically no night stations at which it was not present, but there is no doubt that it is a patchy species and it sometimes occurs in dense local concentrations. During the 1927–31 period 2000–3000 have been taken on several occasions, and some very big hauls were taken off South Georgia during the first commission of the 'Discovery'. Sometimes, however, it is distributed quite evenly over a large area.

Primno macropa. This species seems to have no particular limits to its distribution in the Antarctic. It is perhaps slightly commoner in the warmer waters, but it is found in small numbers almost everywhere. There is no evidence of any tendency to form shoals or local concentrations.

Vibilia antarctica. Found everywhere from the convergence to the Bellingshausen and Weddell Seas. It seems to be of very regular occurrence around the South Orkneys. It never occurs in very large quantities.

Eusirus antarcticus. Another strictly cold-water species whose northern limit corresponds closely with that of *Diphyes antarctica.* Few specimens have been taken and there is no reason to suppose that its distribution is at all patchy.

Cyllopus spp. Quite evenly distributed from the convergence to the colder regions. As a genus it seems to have no preference for either the warmer or colder parts of the Antarctic, and there appears to be no tendency towards local concentrations.

Antarctomysis sp. This must be classed as a neritic genus. Among the samples upon which the present paper is based it has been found only in the South Georgia and South Sandwich region, but according to Rustad (1930, Mysidacea, p. 20) its distribution is circumpolar. The greatest number have been taken from the shallow water on the south side of South Georgia.

Euphausia superba. In its habits and distribution the "krill", as it is commonly called, stands apart from all other macroplankton species. It will form the subject of separate publications, and it will suffice here to say that it is seldom found north of a line running from the north side of the South Shetland Islands north-eastwards past the western end of South Georgia, and it has not so far been taken in any large numbers in the Bellingshausen and eastern Weddell Seas. It is one of the few species which are found in occasionally large numbers in the coastal region of the South Orkneys and South Shetlands. The average number for all hauls (see Table II, p. 97) shows that numerically it is among the most abundant of macroplankton species, and in mass of living matter it might well be equal to all the rest of the Antarctic macroplankton combined. In its distribution it is the most patchy and irregular of these species, and the great majority of specimens have been taken from actual shoals.

Euphausia frigida. This species occurs mainly in the warm waters of the outer Antarctic Zone and in the outflowing Weddell water in the South Sandwich neighbourhood.

In the coastal region of the South Orkneys and South Shetlands and in the Bellingshausen Sea it occurs sometimes in small numbers. It was not taken at stations in the eastern Weddell Sea. In general it occurs in varying quantities but appears never to form shoals.

Euphausia crystallorophias. Like *Antarctomysis* this must be regarded as a neritic species. It is found, however, only in the colder regions such as the Bransfield Strait and the coastal waters of the eastern part of the Bellingshausen Sea.

Euphausia triacantha. This species occurs in a more strictly limited zone than perhaps any other. To the north it is found only a little way beyond the convergence and to the south it is bounded normally by a line from the South Shetlands running north-eastwards and passing a little to the south of South Georgia. It is thus a typically warm-water species, but it is curious that it does not normally extend far into the sub-Antarctic Zone as do most of the other species typical of the warmer parts of the Antarctic. This fact may perhaps be in some way due to the depth at which it lives. There is no reason for supposing that it forms shoals or local concentrations.

Euphausia vallentini. This is really a sub-Antarctic species, but it sometimes strays south of the convergence and has even been taken off South Georgia on one or two occasions. Zimmer (1914) records a specimen from 58° 29′ S, 89° 58′ E, a very high latitude for this species.

Thysanoessa spp. There have been very few samples which did not contain representatives of this genus. It seems always to be scarce in the Bellingshausen and eastern Weddell Seas, but in the warmer parts of the outer Antarctic, in the outflowing Weddell water and around South Georgia it is often taken in thousands. As a genus it is very variable and patchy, and this characteristic is probably shared by *T. macrura* and *T. vicina.*

Cleodora sulcata. Distributed everywhere from the Bellingshausen Sea to the coldest regions. In most places it is taken normally in ones and twos, but it is more plentiful in the Weddell Sea water in the neighbourhood of the South Sandwich Islands. Here there have been single hauls containing several hundred specimens, and such hauls might be regarded as indicating at least a local concentration. It is distinctly a cold-water species.

Limacina helicina. This is pre-eminently a cold-water species, but at times it is found as far north as the convergence. There are no very definite limits to its distribution, but its occurrence seems to vary according to the time of year. There is no indication that it forms shoals or dense local aggregations such as we find in the case of *L. balea.*

Limacina balea. The distribution of this species is quite different from that of *L. helicina.* The two are sometimes found together, but *L. balea* is more of a warm-water species and seems to reach its greatest development near the convergence. No specimens have been taken in the Bellingshausen Sea or in the eastern Weddell Sea, though it occurs in the outflowing Weddell water. In the warmer parts of the Antarctic water it has occasionally been found in enormous swarms. Some big catches have also been taken off South Georgia and between South Georgia and Bouvet Island.

Spongiobranchaea australis. Found everywhere from the convergence to the coldest regions. It is very evenly distributed, but is possibly a little commoner in the warmer water than elsewhere. There are rarely more than one or two in a sample and there is no evidence of any tendency to form shoals or local concentrations.

Clione antarctica. This species also is widely distributed, but it is rather commoner in cold than in warm water. It is occasionally found as far north as the convergence. On the whole it is very evenly distributed, occurring generally in very small numbers and showing no tendency towards forming local aggregations.

Salpa fusiformis f. *aspera.* Found everywhere from the convergence to the Bellingshausen and Weddell Seas. Its distribution is not unlike that of *Metridia*, for it has been caught in large numbers at all the night stations and at most of the day stations in the vicinity of the South Orkney Islands. It seems that there is nearly everywhere a sprinkling of Salps, and here and there a dense patch. Catches in the South Sandwich region have all been small, but big hauls have been taken off South Georgia and one large aggregation has been met with in the Bellingshausen Sea. The shoaling tendency of the Salps is of a different type from that of the "krill". The former seem occasionally to be concentrated in large areas where the numbers reach a maximum in the centre. A typical example is provided by seven successive stations (564–70), covering some 300 miles in the Bellingshausen Sea. At these the numbers of Salps taken were, respectively, 0, 4, 66, 550, 369, 57, 0. *Euphausia superba* occurs in smaller, denser and more numerous shoals.

Chaetognatha. This group, which is principally made up of *Eukrohnia hamata*, is found in the greatest numbers in the outer, warmer part of the Antarctic water, and the largest catches have, in general, been those closest to the convergence. Large numbers are not likely to be taken south of a line running from the South Shetlands to South Georgia, but some quite large catches have been taken in the western Bellingshausen Sea. The distribution of the Chaetognatha appears on the whole to be very regular, and it would appear that *Eukrohnia hamata*, at any rate, does not tend to form shoals. This species, according to Bigelow and Leslie (1930, p. 564), "ranges from Arctic to the Antarctic in the Atlantic, being confined to the bathyplankton in low and mid-latitudes".

It will be seen from the foregoing notes that the macroplankton can be divided very roughly into three groups: (i) those species which have a definite preference for, or which are actually confined to, the cold water or high latitudes, (ii) those which are definitely typical of the warmer water or lower latitudes, and (iii) those which may be found everywhere and may be taken in maximum numbers in both the warmer and colder regions.

It has been explained that the Antarctic surface water in the greater part of these regions is drifting mainly in an easterly or north-easterly direction, and, as we should expect, the isotherms are roughly parallel to the direction taken by the oceanic currents (see Fig. 22). In Fig. 21 lines are drawn to show the distributional boundaries of those species which show a clear limitation of distribution. For instance, no specimen of *Euphausia vallentini* has been taken at any station on the south side of line No. 4, and none of *Diphyes antarctica* to the north of line No. 1. *Euphausia superba* may be found in large numbers anywhere south of line No. 1, but is very rare to the north of it. It will be seen that the majority of these lines also run roughly parallel to the direction of drift, and indeed it would be surprising if they did not. It is one thing, of course, to say that a species has not been found to the north or to the south of a particular line, and another thing to say that it never occurs there. It must be emphasized therefore that the lines shown on this chart are tentative. The utmost that can be inferred with certainty is that there is a belt of change between South Georgia and the South Shetland Islands. That is to say, an observer moving in a north-easterly direction in this part of the Antarctic water would find few qualitative changes in the plankton, whereas if he

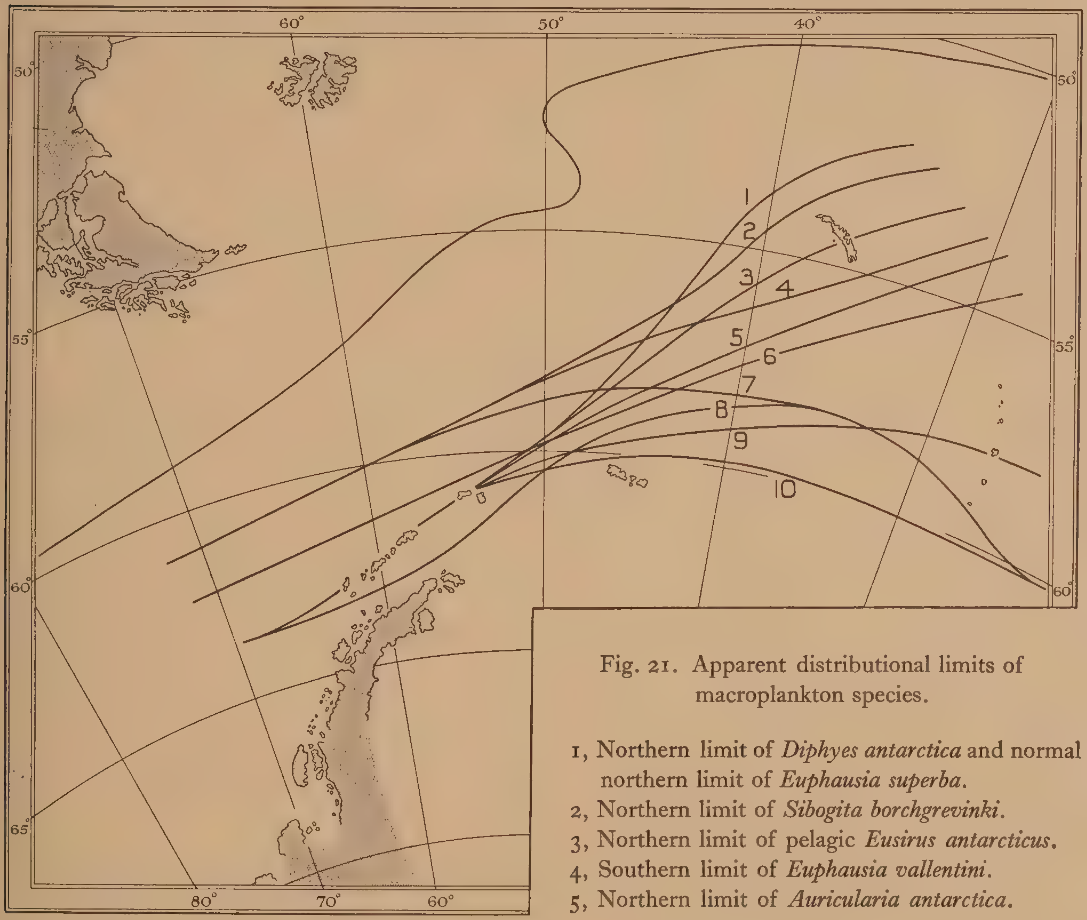

Fig. 21. Apparent distributional limits of macroplankton species.

1, Northern limit of *Diphyes antarctica* and normal northern limit of *Euphausia superba*.
2, Northern limit of *Sibogita borchgrevinki*.
3, Northern limit of pelagic *Eusirus antarcticus*.
4, Southern limit of *Euphausia vallentini*.
5, Northern limit of *Auricularia antarctica*.
6, Southern limit of *Euphausia triacantha*.
7, Southern limit of *Candacia* sp.
8, Southern limit of *Limacina balea*.
9, Southern limit of *Calanus simillimus*.
10, Southern limit of *Pleuromamma robusta* and northern limit of *Haloptilus ocellatus*.

travels south-eastwards across the line of the isotherms he will meet with important changes, especially while crossing a belt running approximately from the South Shetland Islands to South Georgia. This zone of rapid qualitative change will be mentioned again in a later section. The point to be emphasized at the moment is that the chart indicates a connection between the distribution of species and the surface temperature of the water within the Antarctic Zone. This temperature ranges from nearly – 2° C. to about + 5° C., and a quantitative comparison of the different species in respect of their occurrence in water of different temperatures will provide a clearer distinction between the warm- and cold-water species than is given in the notes on general distribution.

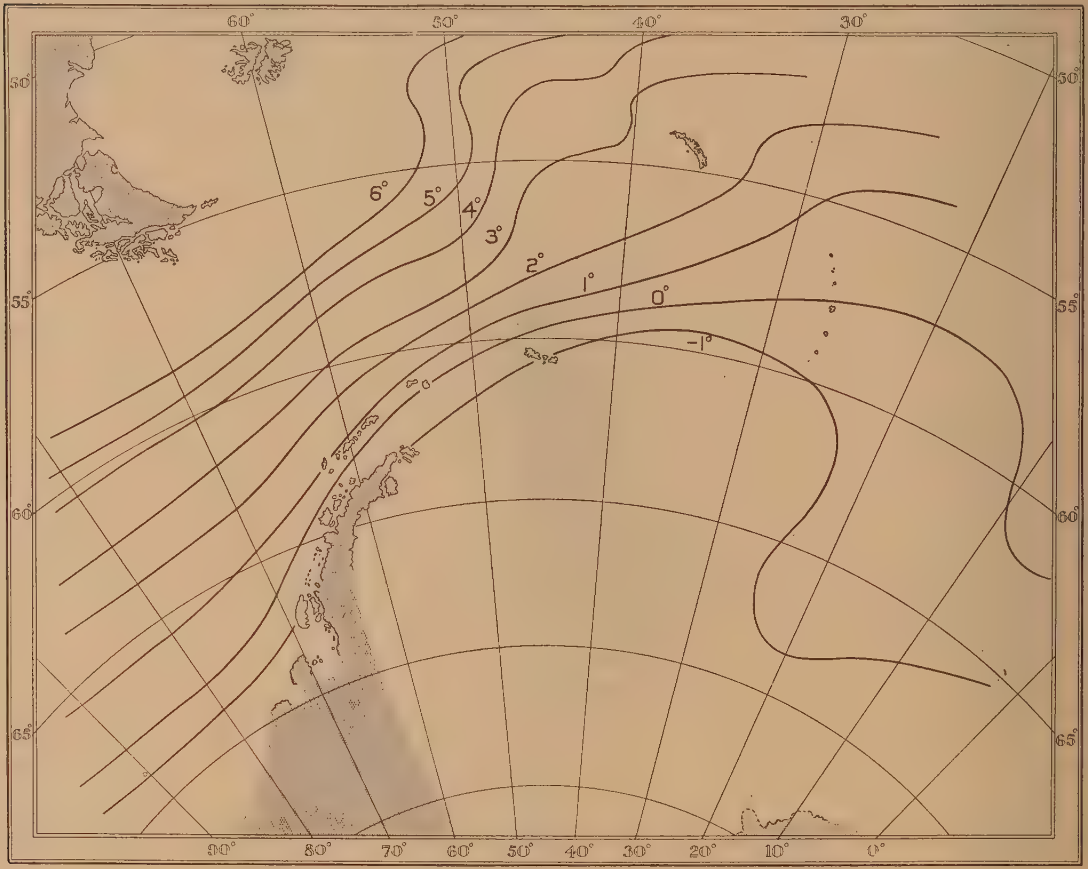

Fig. 22. Approximate positions of the mean summer isotherms.

It must be supposed that plankton organisms which have an optimum temperature cannot make active movements to avoid changes in temperature caused by the seasons, the weather, the approach and departure of ice, etc. We should therefore expect more reliable results from the mean temperature of the locality than from the actual temperature of the water in which a species is taken. It would be desirable if possible to compare the distribution of a species with the temperature of the water at the mean depth at which it lives. But at a great many of the stations at which the N 100 B was used the

Table III. *Distribution and temperature.*
Average numbers per haul between the mean summer isotherms

Isotherms: ° C.... ...	− 1·00 to − 1·99	0·00 to − 0·99	0·00 to 0·99	1·00 to 1·99	2·00 to 2·99	3·00 to 3·99	4·00 to 4·99	5·00 to 5·99	6·00 to 6·99
Warm-water species									
(*a*) Practically confined to water above 3° C.									
Euphausia vallentini	—	—	—	—	0·08	4·80	29·1	370	44·1
(*b*) Typical warm-water species.									
Eucalanus sp.	—	—	—	2·80	7·90	17·3	14·4	49·8	96·9
Candacia sp.	—	—	2·30	—	3·80	13·8	5·00	20·8	18·7
Heterorhabdus sp.	—	—	12·1	0·40	3·56	8·80	5·14	11·4	16·3
Euphausia triacantha	—	—	0·88	5·18	21·8	10·2	18·7	32·1	7·00
Calanus simillimus	—	—	5·80	28·3	190	344	82·0	871	293
Pleuromamma robusta	—	5·20	3·40	73·1	201	40·0	146	104	252
(*c*) Warm-water species sometimes found in colder regions.									
Chaetognatha	785	98·2	53·5	129	375	532	763	1550	2320
Limacina balea	—	11·7	813	4·70	97·8	22·6	250	3940	710
Pareuchaeta sp.	72·0	24·8	25·5	140	200	32·5	216	250	63·7
Parathemisto gaudichaudi	0·50	2·90	26·3	23·1	129	182	38·8	148	179
Euphausia frigida	—	7·00	581	150	341	245	205	—	0·20
Widespread species									
(*d*) Species found on all isotherms but with a slight preference for warmer water.									
Primno macropa	2·62	0·46	0·37	1·00	1·50	3·94	9·54	5·50	—
Spongiobranchaea australis	0·20	0·16	0·40	0·63	0·41	2·37	0·36	0·44	1·00
Thysanoessa spp.	48·5	147	513	1100	1120	1160	954	1220	1220
Rhincalanus gigas	2460	1270	393	755	2470	1443	1137	1060	1110
(*e*) Neutral species.									
Haloptilus sp.	51·2	0·02	0·95	0·19	2·68	0·42	4·00	6·15	—
Euchirella sp.	—	4·20	15·2	—	9·60	1·20	—	9·70	2·50
Solmundella sp.	—	0·48	0·96	0·36	0·62	0·22	1·14	1·33	4·57
Cyllopus spp.	0·50	1·04	0·82	1·40	1·10	1·00	0·37	0·33	0·67
(*f*) Species found on all isotherms but with a slight preference for colder water.									
Calanus acutus	8830	1100	1500	1110	1530	492	87·1	189	9·60
Vibilia antarctica	4·16	2·58	1·40	0·67	2·98	0·40	0·25	0·14	—
Calanus propinquus	296	540	1530	2510	811	327	577	265	20·0
Cold-water species									
(*g*) Cold-water species which may occur in large numbers anywhere south of the 3° isotherm.									
Euphausia superba	1·00	336	434	822	1700	95·4	1·80	0·10	0·10
Cleodora sulcata	3·33	2·55	5·75	81·8	0·69	0·10	0·37	0·14	3·00
Salpa fusiformis f. *aspera*	16·6	52·4	79·8	56·4	24·8	11·4	4·60	6·40	40·4
Tomopteris sp. (large)	1·27	0·52	0·60	1·17	0·98	0·21	0·18	—	0·14
Tomopteris sp. (small)	18·0	36·1	5·70	5·00	4·70	2·20	1·00	3·70	9·40
Metridia gerlachei	421	543	289	538	117	68·0	26·7	1·30	—
Clione antarctica	5·89	2·64	1·60	1·37	0·91	1·25	0·56	0·25	—
Limacina helicina	80·2	19·5	25·5	41·6	7·20	7·60	5·50	3·00	—
Pyrostephos vanhöffeni	22·6	32·0	5·30	14·4	8·90	3·30	1·40	3·50	3·30
(*h*) Species typical of the coldest regions, which rarely or never approach the convergence.									
Sibogita borchgrevinki	0·27	0·10	—	0·08	0·12	0·07	—	—	—
Dimophyes arctica	14·4	7·80	0·80	2·20	1·70	—	—	0·20	1·40
Vanadis antarctica	7·27	0·19	0·77	0·03	0·08	—	—	0·42	0·67
Diphyes antarctica	2·09	1·48	0·67	1·61	0·08	—	—	—	—
Eusirus antarcticus	1·57	0·95	0·70	0·07	0·10	—	—	—	—
Auricularia antarctica	4·55	2·50	0·31	0·19	0·02	—	—	—	—
Haloptilus ocellatus	108	24·8	0·40	—	—	—	—	—	—
Neritic species									
Antarctomysis sp.	—	—	—	38·0	48·0	—	—	—	—
Euphausia crystallorophias	—	1·06	0·07	—	—	—	—	—	—

temperature was taken only at the surface. However, the mean surface isotherms bear a sufficiently uniform relation to the mean isotherms at 50 or 100 m. and will serve our purpose here. Since the great majority of stations have been taken in the summer months a much more reliable chart can be constructed of the mean summer isotherms than of the mean annual isotherms. Either would suffice, however, for we are seeking a relative and not an absolute correlation. Fig. 22 shows the mean summer isotherms and is a provisional chart derived from temperatures recorded in the three seasons 1928–31.

In Table III the species are arranged in order of their apparent preference for warm or cold water. The figures in the table represent the average number of each species per haul. Samples have been disregarded where the haul was made at a time of day when the diurnal variations of any particular species precluded the taking of a representative sample. Catches in the Bransfield Strait, where the plankton is disproportionately thin, have usually been omitted, and for all but one or two of the rarer species, only one station has been counted for each line of stations in each South Georgia survey. The end station of the line is taken, or the outermost one permitted by the diurnal variations. The actual figures are much influenced by variations in the general richness of the plankton in different localities, or by patchiness of the plankton, and are therefore individually unreliable. Thus the "– 1°" column depends almost entirely on a few stations in the Bellingshausen Sea, west of Peter 1st Island, where the plankton was particularly rich, and the figures in this column are consequently deceptively high. The actual figures are therefore used only as the principal basis of a general grouping of the species according to the temperature belt they mainly inhabit.

The table shows the distinction between the warm-water species, the widespread species, and the cold-water species. The neritic species are unimportant and are shown in a separate category. There is of course no very hard and fast distinction between the main groups or the subsidiary groups, and a larger body of data might bring about some modification of the order in which the species are listed.

It is interesting to compare this table with the table of mean diurnal variations, for it will be seen that the warm-water species are mostly those which have the most marked diurnal variations and many of the cold-water species have no significant variations. There are exceptions, for *Parathemisto* shows little diurnal variation, while *Salpa* and *Metridia* vary considerably. Hardy and Gunther (1934), however, find a distinct vertical migration in *Parathemisto*. The phenomenon is no doubt partly connected with the reduction or absence of darkness in summer in the high latitudes inhabited by the cold-water species, but the question will not be pursued any further here, since it can be more properly dealt with when the samples from the 24-hour stations have been finally worked out.

DISTRIBUTION OF RICH AND POOR PLANKTON

It is well known that as a general rule the plankton of the surface waters of the tropics is very thin, that in the temperate regions it is richer, and that in the Arctic and Antarctic it is comparatively abundant. Murray and Hjort (1912) mention that "the closing nets of the 'Michael Sars', when hauled from 200 m. to the surface in the Sargasso Sea, yielded on the average 3 c.c. of plankton, while in the Norwegian Sea from 85 to 225 c.c. were obtained in numerous similar hauls". According to Jespersen (1923) the volume of macroplankton in 50–60° N in the North Atlantic is 10–20 times as great as in 20–30° N. The upwelling in the Antarctic Zone of water rich in nutrient salts results in a luxuriant development of phytoplankton, and this in turn supports an abundant animal plankton. Hart (1934) mentions the richness of the Antarctic phytoplankton, and Hentschel (1928) and Hentschel and Wattenberg (1930) publish charts of the South Atlantic which show the association of areas of rich plankton with the areas of upwelling of cold water.

The richest plankton of all is found in the Antarctic surface water, but it is by no means uniformly abundant over the whole of the Antarctic Zone. The quantity of macroplankton, for instance, varies very much at different times and in different places, and these variations so far as they can be ascertained from the present material will be described in the following pages.

A chart showing the distribution of the total number of organisms per haul is roughly representative of the distribution of the richness of plankton, though it does not necessarily illustrate the distribution of the majority of species. It represents rather the half-dozen commonest species. But the main difficulty in charting the richness of the plankton is, perhaps, that there is no quite satisfactory means of allowing for diurnal variations, since different samples have different proportions of the variable species. However, the few species like *Calanus acutus* and *Rhincalanus gigas*, which make up the bulk of the plankton, do not have a very marked diurnal variation and the time of day has a far smaller effect on the amount of plankton in a sample than the actual distribution of quantity.

GENERAL DISTRIBUTION

Fig. 23 shows the numbers of organisms taken at all stations in January, February and March in all four seasons (1927–31), with the exception of the intensive lines of stations taken in the South Georgia and Bransfield Strait surveys. The figures stand for the number of hundreds of organisms in each sample, but the shoaling species, *Euphausia superba*, *Limacina balea*, and *Salpa fusiformis* are omitted. For instance at WS 551, the last station on the line to the eastern Weddell Sea and marked 56, just over 5600 organisms were taken. Although the diurnal variations have a minor effect on the total contents of a sample, the figures are shown in italics for hauls made in daytime between the hours of 0600 and 1700. The shading is based purely on the figures shown on the chart, and is intended merely to draw attention to the positions at which large, medium or small hauls were taken.

This chart shows that around the coasts of Graham Land, the South Orkneys, the South Shetlands, Adelaide Island, Alexander 1st Land, etc., the summer plankton is very thin. Away from this region in all directions it seems that the richness of the plankton increases, and reaches a maximum in the South Georgia and South Sandwich region, and to the west of Peter 1st Island in the Bellingshausen Sea.

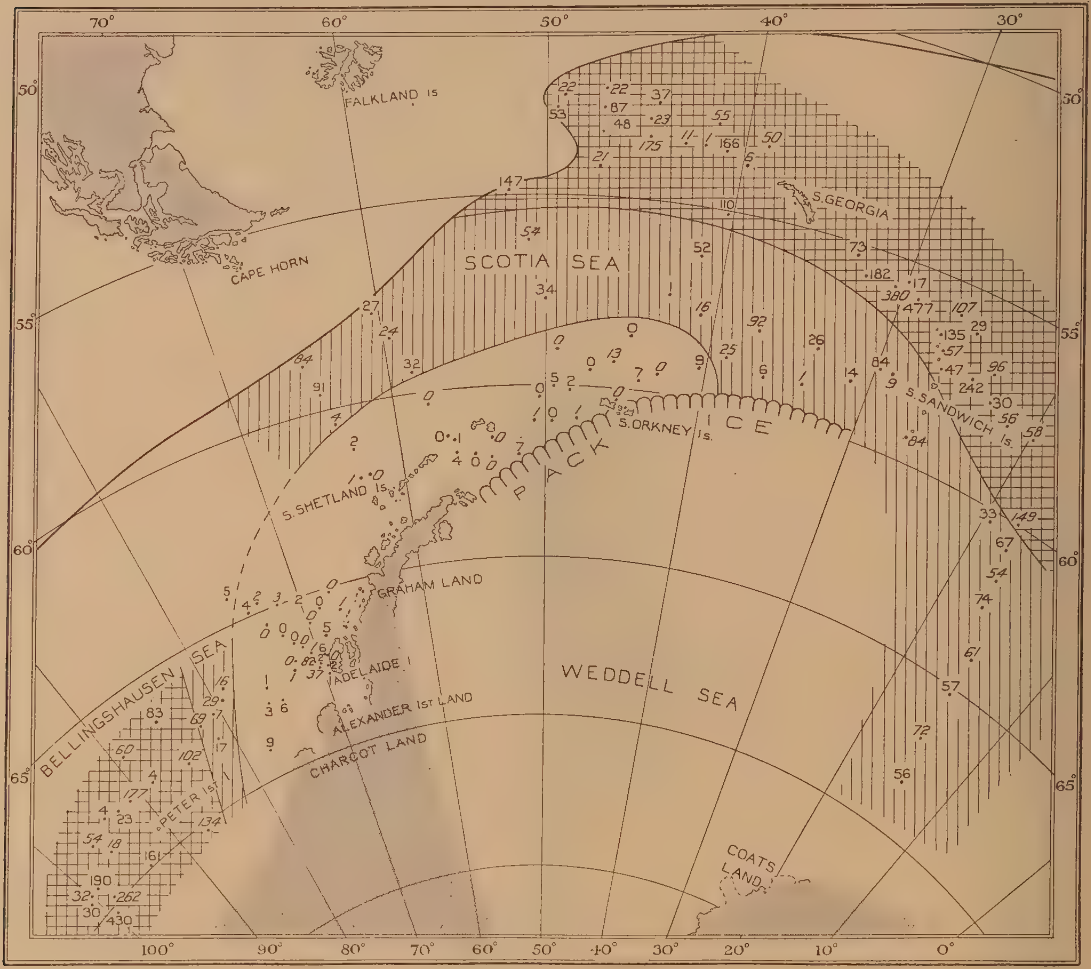

Fig. 23. Distribution of macroplankton quantities in summer. Figures show the number of hundreds of organisms in each sample, shoaling species being omitted. Those in italics are day hauls and others are night hauls.

There can be no doubt of the contrast which normally exists between the South Georgia and Graham Land areas, for these regions have been visited many times in a succession of years. Nor can there be any doubt that the outer parts of the Antarctic water between South Georgia and the Falkland Islands, harbour a quite rich plankton during at least a large part of the summer. Cruises in the Bellingshausen and Weddell Seas have been made on fewer occasions, but it is probable that there is always a rich summer plankton in these regions.

It may be mentioned that Hart (1934) finds that the Bransfield Strait is on the average also poorer in phytoplankton than other areas, but the contrast is not so great as it is with the macroplankton.

The reason for the scarcity of plankton around the South Shetlands and South Orkneys cannot at present be stated with certainty, but this is an area in which there is a considerable upwelling of water from the deeper layers, and these deeper layers are of course comparatively poor in plankton. I am informed by our hydrologists that the region of thin plankton shown in Fig. 23 coincides roughly with an area in which the surface water has been found to have a low oxygen content. This suggests that the water has recently risen from a deeper level where the consumption of oxygen has not been balanced by exposure to air. It is curious that some species, such as *Euphausia superba* and *Salpa fusiformis*, are nevertheless sometimes found in large numbers in parts of this area.

VARIATIONS IN ABUNDANCE

There is evidence to show that in the course of the year certain changes take place in the distribution of the amount of plankton, and although these changes cannot be followed with certainty at the present stage it is worth while to consider the material in some detail. It has not been found practicable to make a series of repeated observations in one place throughout a year or part of a year, and it will be necessary to compare the conditions in, for instance, December in one season with April in another season, and so on. Conclusions drawn in this way must of course be formed with caution.

South Georgia

Figs. 24–30 represent the results of successive surveys of the South Georgia whaling grounds in the four seasons 1927–31, and they are constructed on exactly the same lines as Fig. 23.

The essential facts shown by these charts are as follows.

In the 1927–8 SURVEY (February–March, Fig. 24), the plankton was very thin to the north, east and west, but abundant on the south-west side. The increase here was not due to a special development of one species but to a general increase of all the important species.

In the FIRST 1928–9 SURVEY (August–September, Fig. 25), there was a very thin plankton to the west, north, east and south-east. The south and south-west sides were not examined.

In the SECOND 1928–9 SURVEY (December–January, Fig. 26), the plankton was in most places moderate or rather poor, but there was a patch of rich plankton to the south-east. In general it might be called "patchy". Two extra lines (WS 417–26) worked in April of the same season (Fig. 27) produced fairly heavy catches near the south end of the island, but indicated a rather scarce plankton to the south-west.

In the 1929–30 SURVEY (January–February, Fig. 28), the plankton was patchy in places but in general very abundant. In the same season South Georgia was revisited in May. Although the routine N 100 B was not used again, closing N 100 B's were

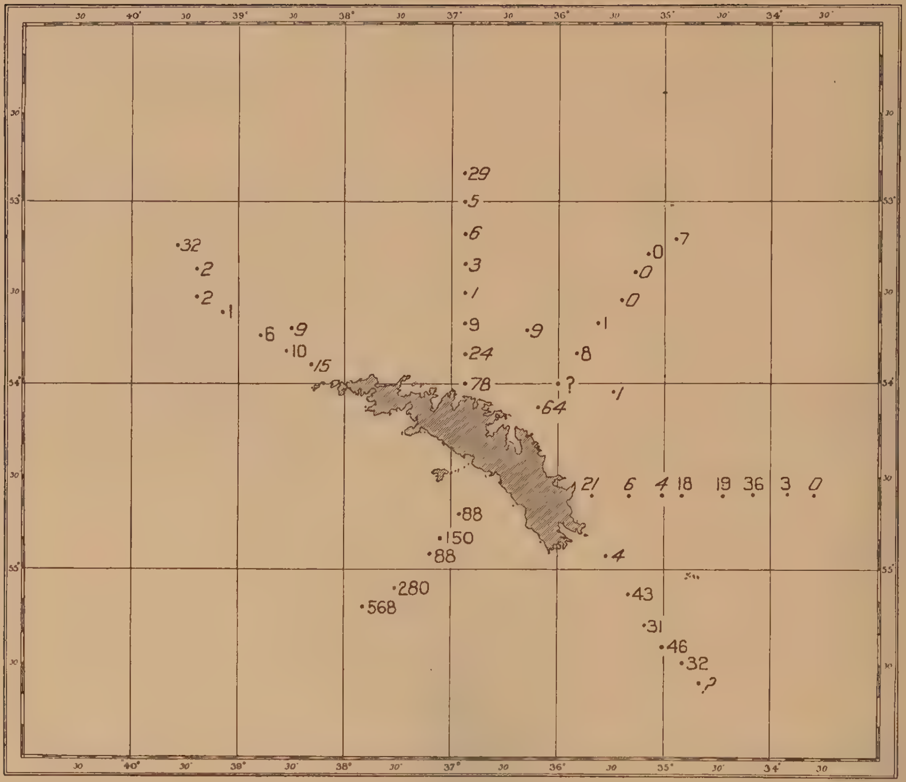

Fig. 24. Distribution of plankton quantities around South Georgia, 1927–8, Sts. WS 144–93.

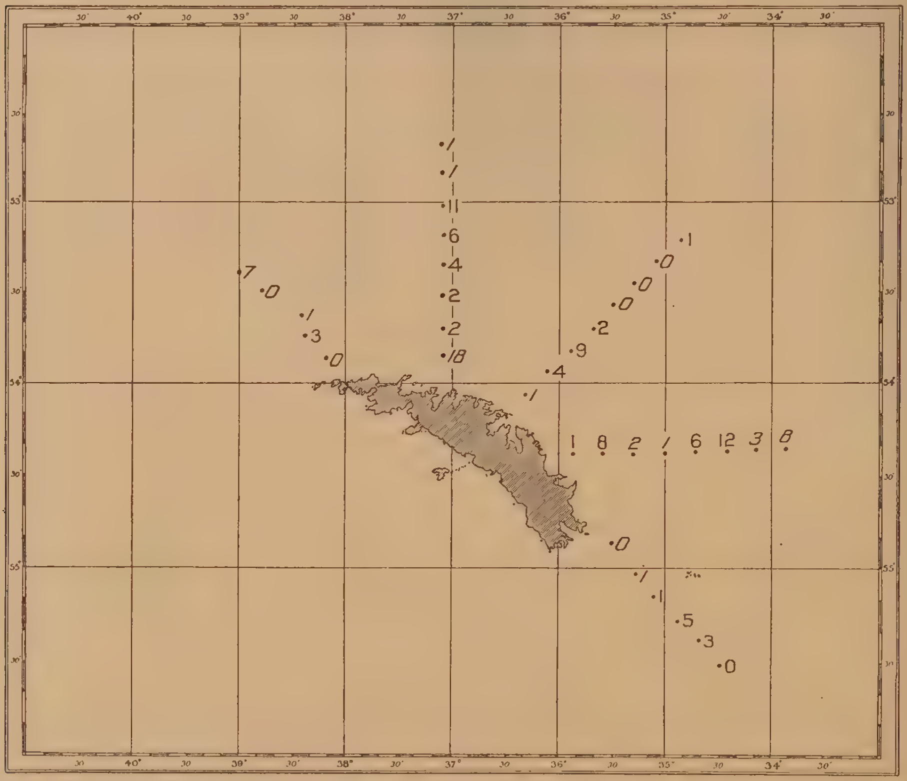

Fig. 25. Distribution of plankton quantities around South Georgia, 1928–9, Sts. WS 257–96.

towed at different levels at an uncompleted 24-hour station (393, see Station List). The catches are not strictly comparable to the routine samples, but they strongly suggest that off the north-east coast in May there was far less plankton than in January.

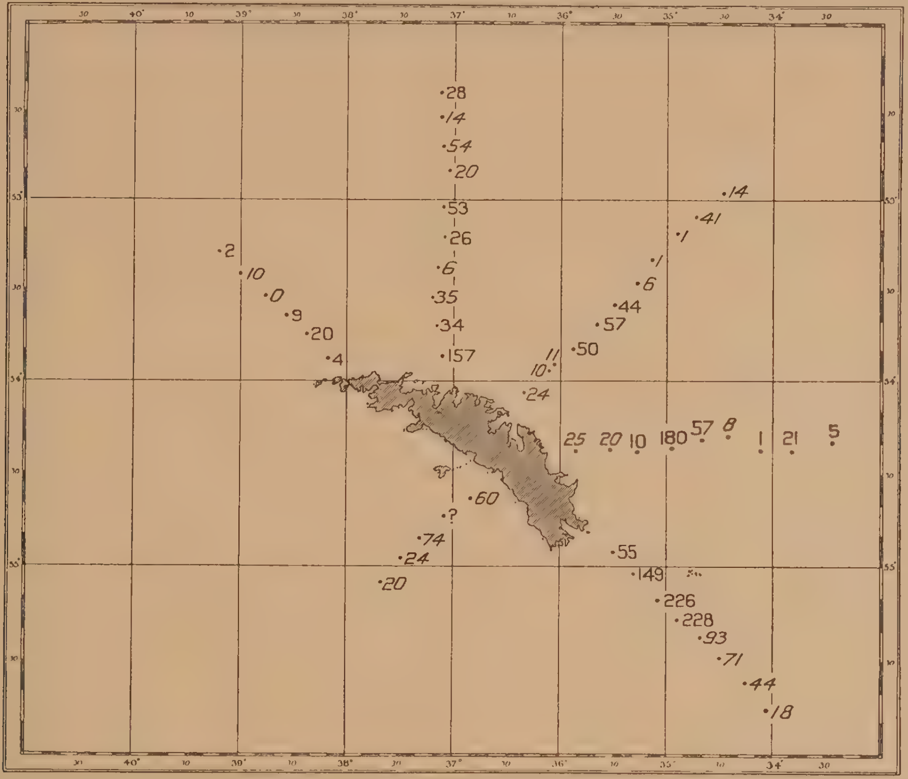

Fig. 26. Distribution of plankton quantities around South Georgia, 1928–9, Sts. WS 321–72.

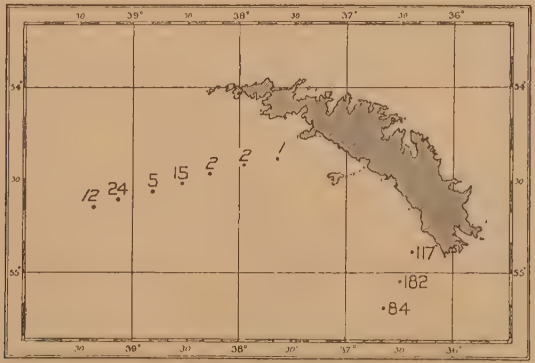

Fig. 27. Distribution of plankton quantities around South Georgia, 1928–9, Sts. WS 417–26.

In the 1930–1 SURVEY (November, Fig. 29), a very rich plankton was again found on the north side of the island, and a slightly less dense population to the south. The line repeated in March in the same season (WS 565–75) showed a considerable reduction in the plankton on the north side of the island (Fig. 30).

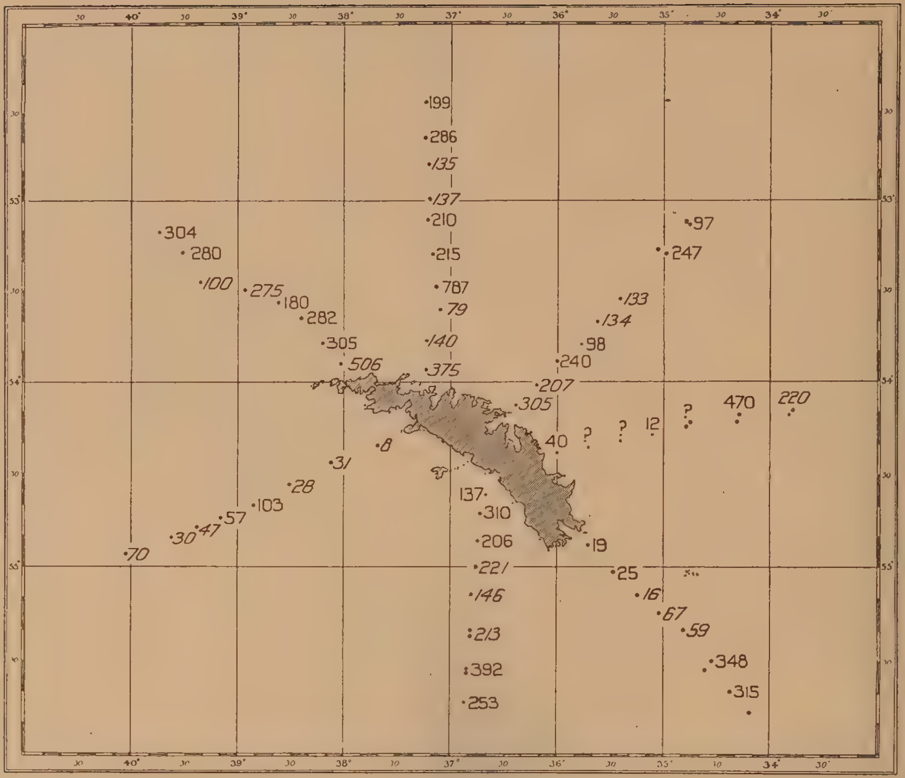

Fig. 28. Distribution of plankton quantities around South Georgia, 1929–30, Sts. 300–58.

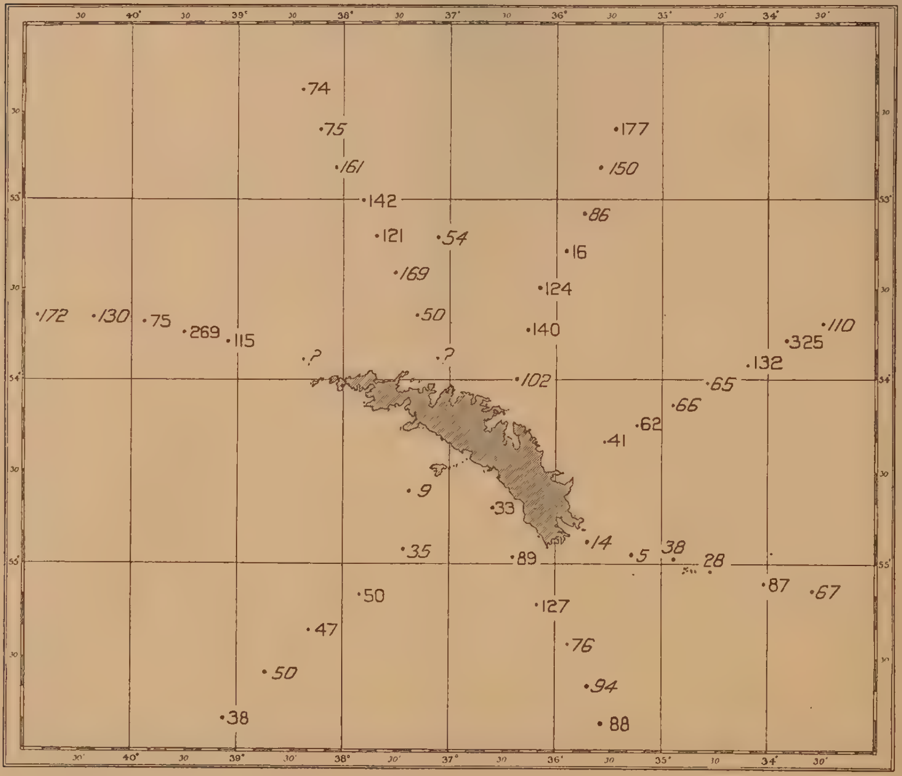

Fig. 29. Distribution of plankton quantities around South Georgia, 1930–1, Sts. 478–525.

The main plankton survey has usually been carried out near the middle of the season, and in those years in which further hauls have been made later in the summer there has been evidence of a reduction in the amount of plankton towards the autumn, at any rate on the north side of the island.

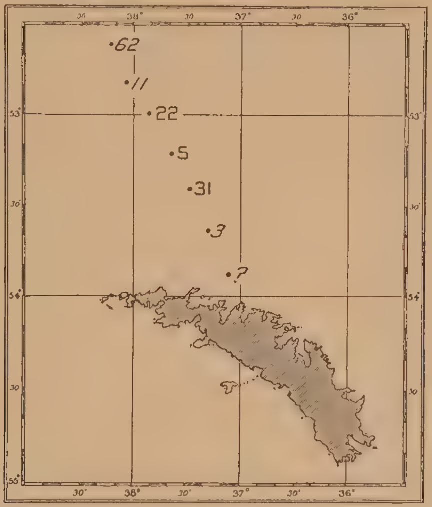

Fig. 30. Distribution of plankton quantities around South Georgia, 1930–1, Sts. WS 565–75.

The following list includes all the N 100 B samples taken in the immediate vicinity of South Georgia during the period 1927–31, and shows the average number of organisms per haul for each group of stations.

Date		Station	Position	Number of hauls	Average number of organisms per haul
1927–8	Feb.–March	WS 144–93	South Georgia survey	44	3,913
	April	WS 196	South-west side of South Georgia	1	2,361
1928–9	Aug.–Sept.	WS 257–96	South Georgia survey	35	468
	October	WS 311	South-east of South Georgia	1	326
	November	WS 313	South-east of South Georgia	1	7,545
	Dec.–Jan.	WS 321–72	South Georgia survey	51	4,674
	April	WS 417–26	South side of South Georgia	10	4,488
1929–30	October	WS 464	North side of South Georgia	1	2,146
	Jan.–Feb.	300–58	South Georgia survey	54	19,224
	May	393	North side of South Georgia	1	(Reduced numbers)
1930–1	November	475–525	South Georgia survey	47	9,485
	March	WS 565–75	North side of South Georgia	7	2,062

In Fig. 31 all four seasons are taken together and the average number of organisms per haul for each group of stations is plotted according to the month or mean date at which the stations were taken. As would be expected the plankton is much richer in the summer than in the winter, but the regularity of the curve is broken by the low figure for the 1928–9 survey (December–January). It is difficult to account for this, but the patchiness of the plankton may be seen from Figs. 24, 26 and 27, and might well result in irregularities in the curve.

Little reliance can be placed on the single stations (WS 311, etc.) for reasons given on p. 71, but it will be seen that they support the suggestion that the plankton increases rapidly about the middle of November. Apart from this no reliance can be placed on the curve, for the reason that the plotted points are derived from different seasons, and the volume of plankton production in these seasons may have been different.

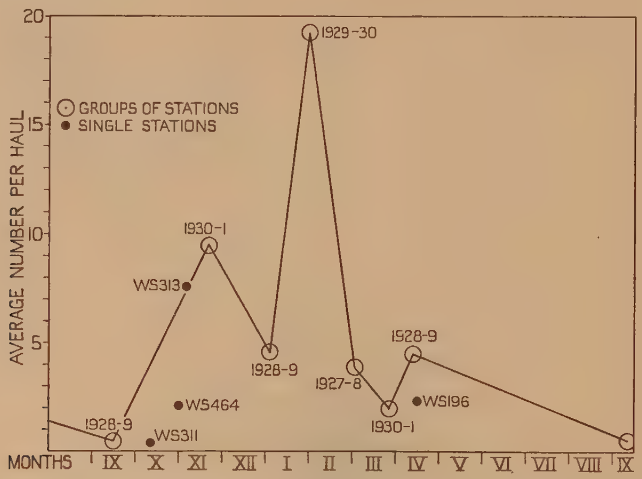

Fig. 31. Quantities of plankton at different times of year around South Georgia. Figures on the vertical scale represent numbers of hundreds of organisms.

If we consider the charts of the four principal surveys in the order of the months in which they were taken, i.e. November 1930–1, December–January 1928–9, January–February 1929–30, and February–March 1927–8, we see that in the earliest (Fig. 29) the richest plankton was mostly grouped to the north of South Georgia, while in the latest (Fig. 24) it was concentrated to the south. In the January–February survey (Fig. 28) it was very rich almost everywhere, but in the December–January survey (Fig. 26) the only rich plankton was a patch to the south-east. It seems possible that there is a tendency for the concentrated plankton to occupy the northern part of the whaling area in the early part of the season, and later to shift down to the south side, and that in 1928–9 the shift for some reason took place unusually early, resulting in the reduction in the average number of organisms per haul in that survey. With the available data we cannot be certain that this shift takes place: it can only be said that there is some evidence for it.

Drake Passage and Scotia Sea

Figs. 32–9 are drawn on exactly the same principle as Fig. 23, but they show the amount of plankton taken at all stations in the Scotia Sea, and each chart shows the stations taken within a single short period. No certain conclusions can at present be drawn from the figures shown, but it will be seen that, while at all times there is a scarce plankton in the vicinity of the South Orkney and South Shetland Islands, the quantity of plankton varies greatly in other places.

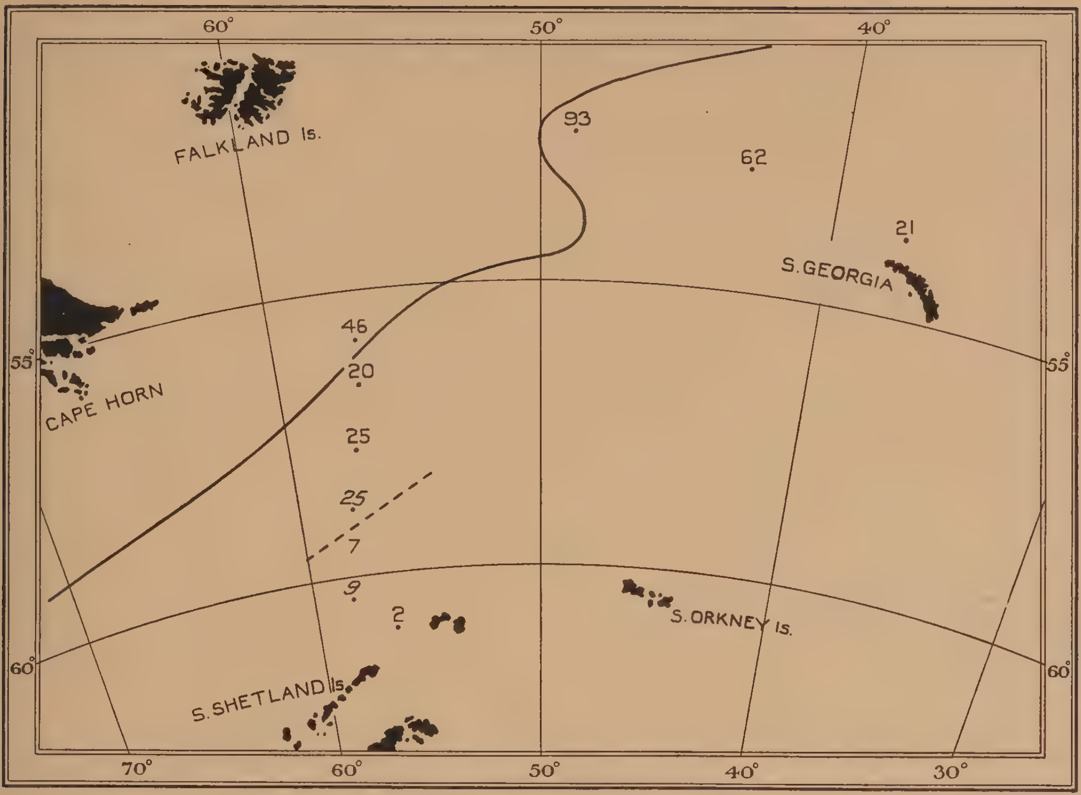

Fig. 32. Distribution of plankton quantities in the Scotia Sea, November 1929–30, Sts. WS 464–74. Figures show the number of hundreds of organisms in each sample, shoaling species being omitted. Those in italics are day hauls and others are night hauls.

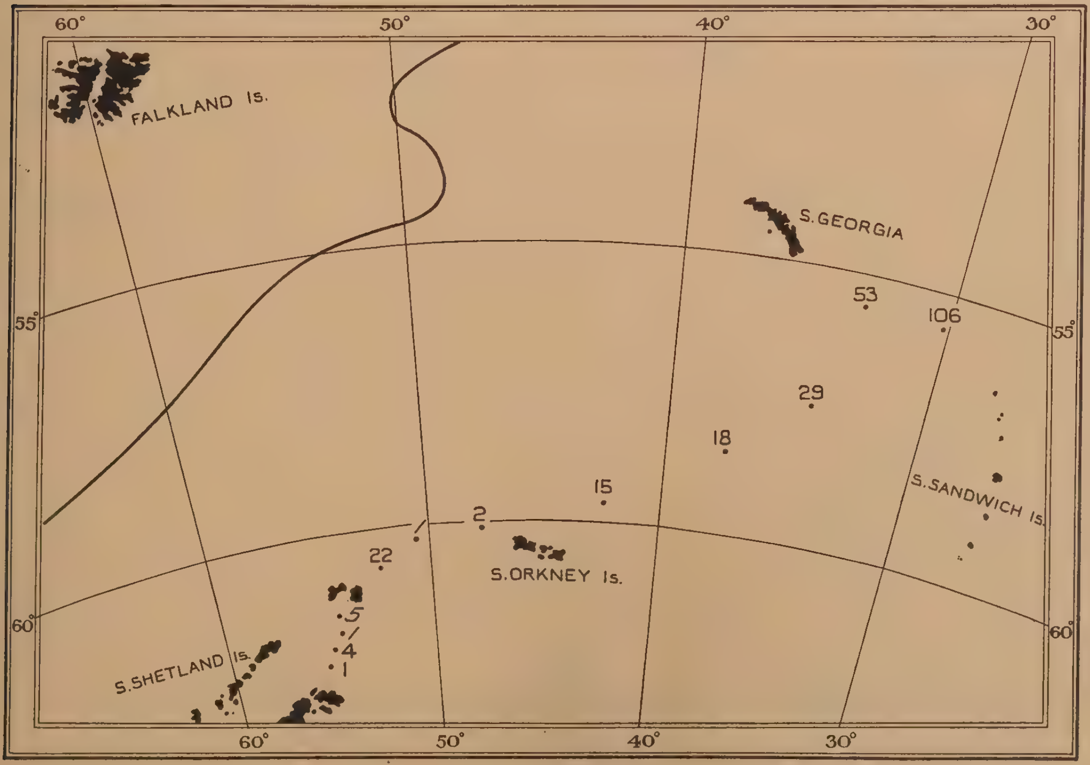

Fig. 33. Distribution of plankton quantities in the Scotia Sea, December 1930–1, Sts. 528–41.

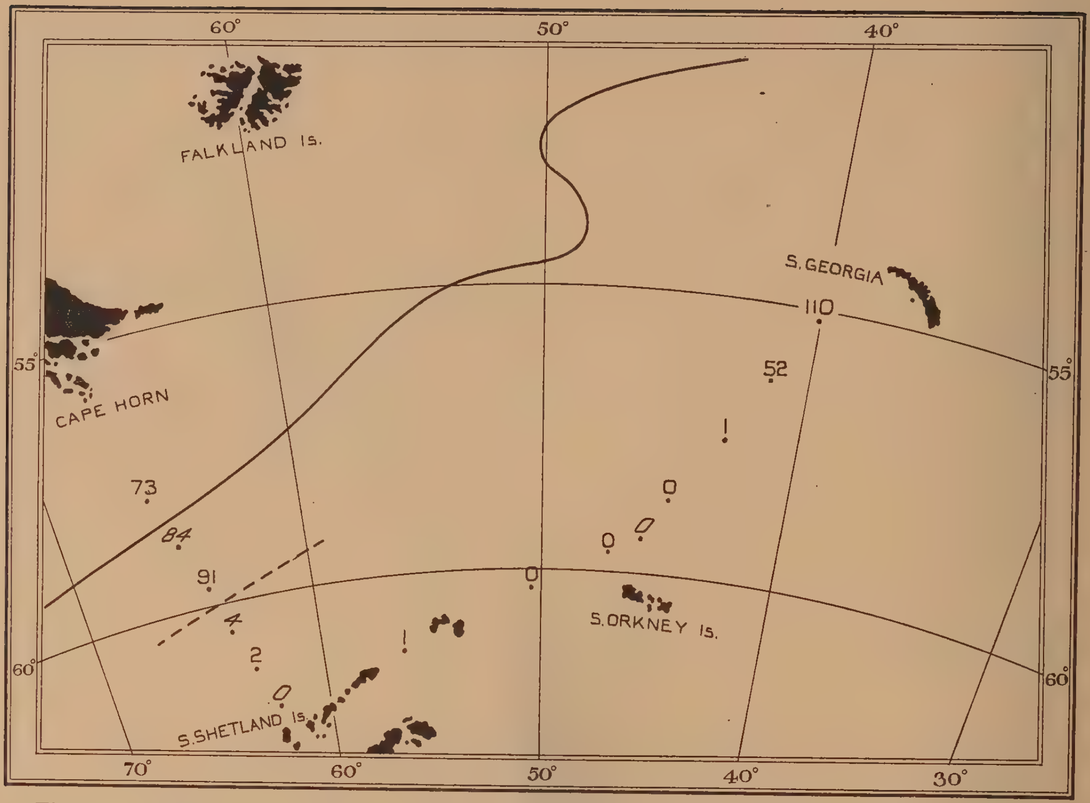

Fig. 34. Distribution of plankton quantities in the Scotia Sea, February 1928–9, Sts. WS 374–405.

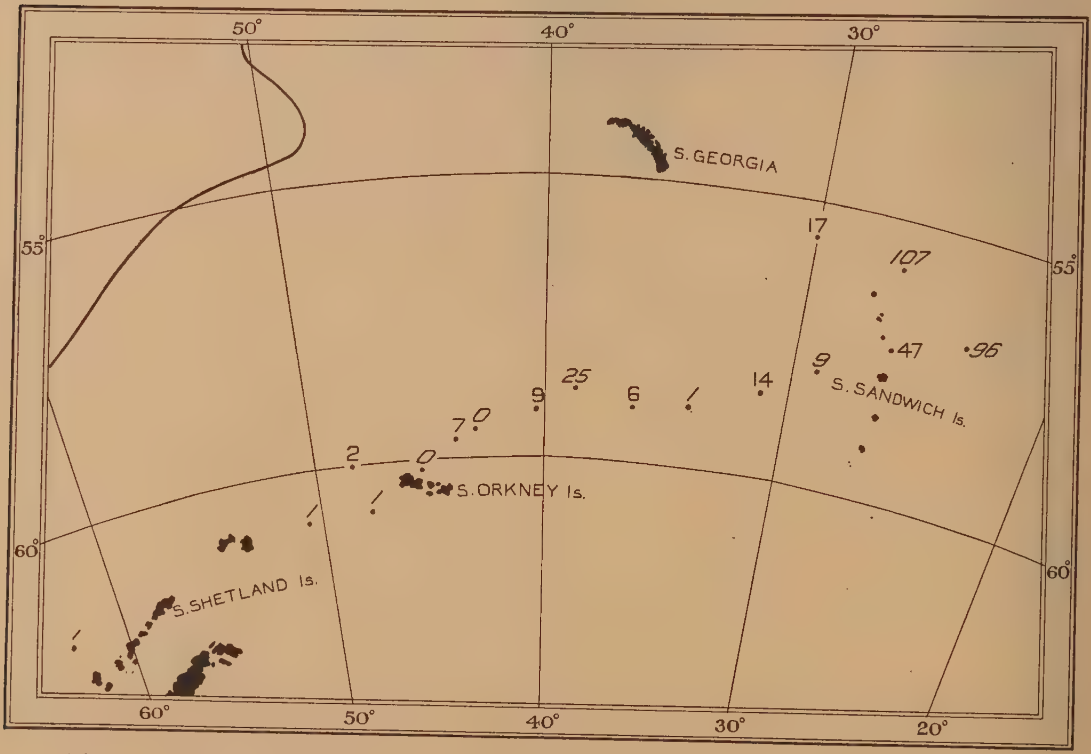

Fig. 35. Distribution of plankton quantities in the Scotia Sea, February 1930–1, Sts. 613–29.

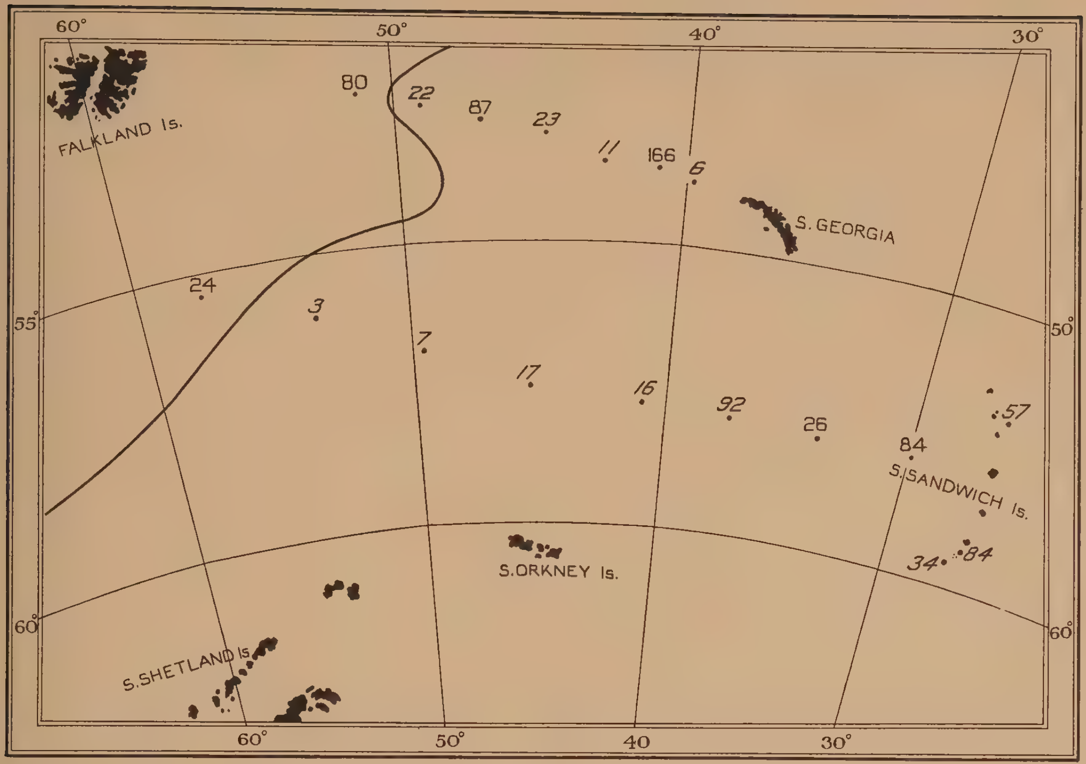

Fig. 36. Distribution of plankton quantities in the Scotia Sea, March 1929–30, Sts. 365–75 and WS 520–30.

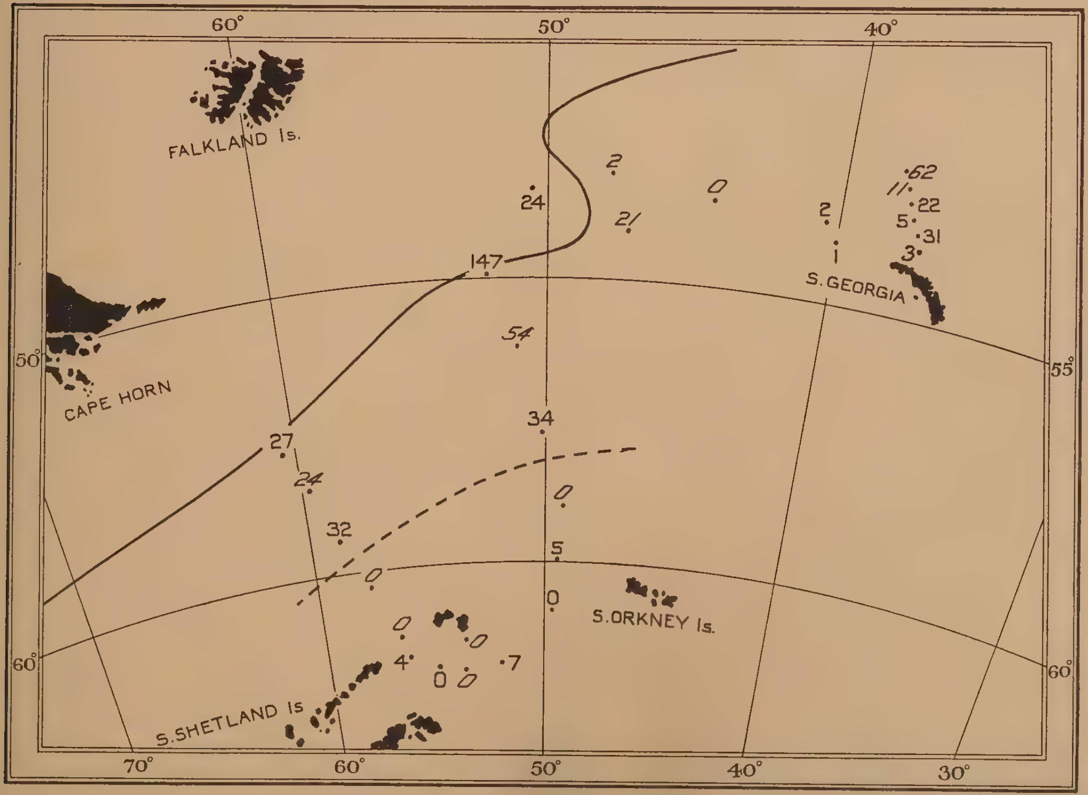

Fig. 37. Distribution of plankton quantities in the Scotia Sea, March 1930–1, Sts. 631–59 and WS 565–75.

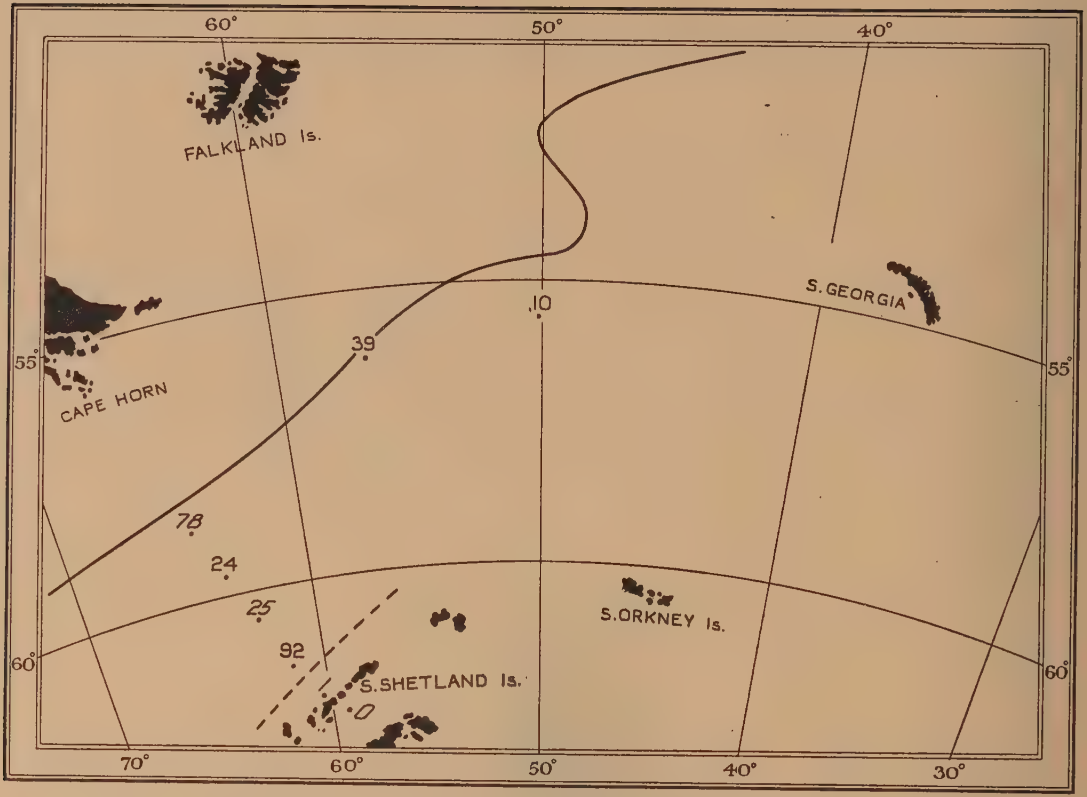

Fig. 38. Distribution of plankton quantities in the Scotia Sea, April 1929–30, Sts. 378–92.

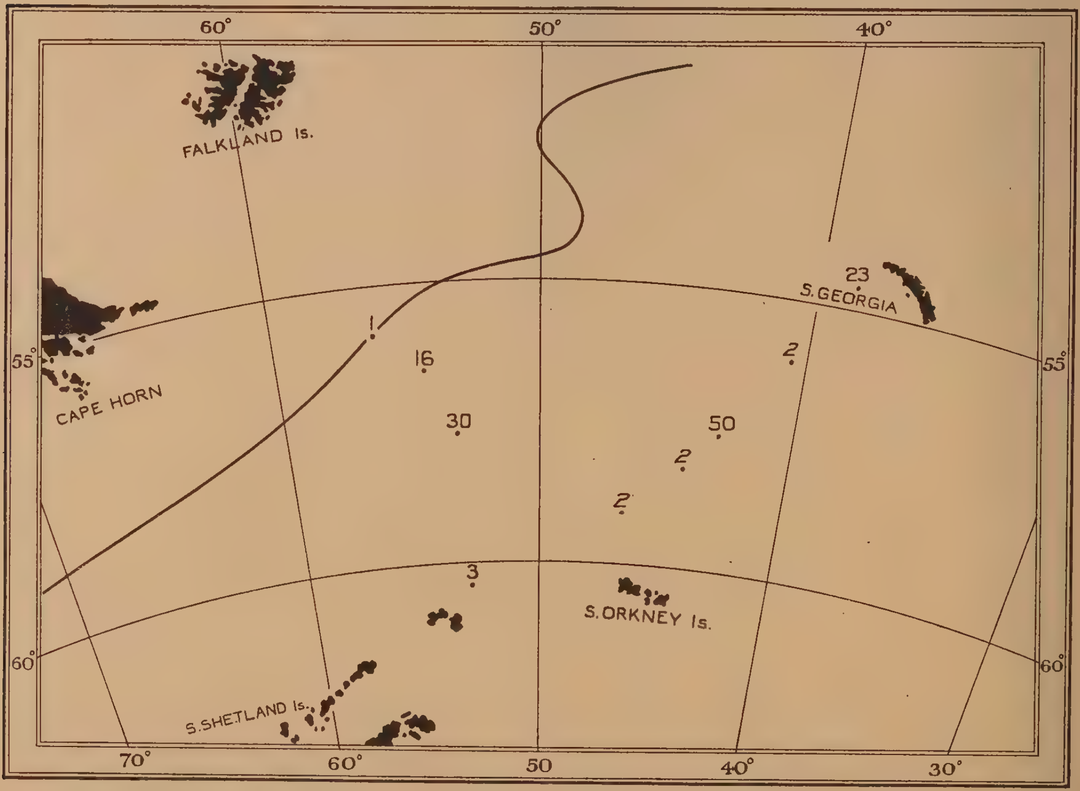

Fig. 39. Distribution of plankton quantities in the Scotia Sea, April 1927–8, Sts. WS 196–205.

These charts are shown primarily as a record for comparison with more recent data or future material, but one interesting point may be mentioned here. In each of the lines of stations between Cape Horn and the South Shetland Islands there is an abrupt change from the rich plankton of the greater part of the Scotia Sea to the thin plankton of the Shetland neighbourhood. The position of the change is indicated by a pecked line in Figs. 32, 34, 37 and 38. If these four figures are compared it will be seen that on the November and February lines (Figs. 32 and 34) the change comes at about 150 miles from the South Shetland Islands, that on the March line (Fig. 37) it is about 100 miles off, and on the April line (Fig. 38) it is only about 30 miles off. From this it seems possible that there is normally a rich plankton in the central part of the Drake Strait which spreads farther south towards the end of the summer. Here comparison is made between different months in different years, so that the apparent shift may possibly be the effect of a coincidence. The results of future work will no doubt settle the question.

If there is in fact such a southward trend of the plankton it would not of course imply an actual transport of plankton towards the south. Such a thing would seem impossible in the present state of our knowledge of the hydrology of these regions. All the evidence goes to show that the Antarctic surface water in these latitudes moves towards the east and north, and there seems no possibility of even a local or periodical deflection towards the south. A more likely explanation might lie in the variation of the amount of upwelling of the "new" water on the south side of the Drake Passage. It has been found that the area occupied by this "new" water extends farthest to the north in midsummer and is most contracted in winter. The boundaries of the "new" water and of the thin plankton do not appear quite to coincide, but there is a similarity in the changes of position of these boundaries. A rich plankton has been found in the Bellingshausen Sea in the neighbourhood of Peter 1st Island, and it is to be supposed that this is carried by the easterly drift towards the Drake Passage. A reduction in the upwelling of water and a shrinkage of the area it occupies in the southern part of the Drake Passage might then make way for the plankton from the Bellingshausen Sea and thus produce the effect of a southerly trend of the rich plankton.

Little can be said of the variations in the quantity of plankton in the more eastern parts of the Scotia Sea. Figs. 32–9 suggest that the plankton may perhaps be a little more patchy in the later than in the earlier part of the summer.

DISTRIBUTION OF WARM- AND COLD-WATER SPECIES

It has been shown that among the Antarctic macroplankton species there are many which prefer, or are confined to, either the warmer or the colder water, but just as there are alterations in the position of the rich and poor plankton, so there are changes in the distribution of the warm- and cold-water species.

SOUTH GEORGIA

Table IV shows, for each species, the average number of specimens per haul for each group of stations off South Georgia. These are the same groups as those listed on p. 115, but the single stations are omitted because they give no reliable indication of the presence or absence of the less common species. The species are listed in order of their preference for warm or cold water, but those which come under the heading of "Widespread Species" in Table III, p. 107, are omitted. The groups of stations (vertical columns) are arranged in order of the months in which they were taken.

Table IV. *Warm- and cold-water species near South Georgia*

	South Georgia survey 1930–1	South Georgia survey 1928–9	South Georgia survey 1929–30	South Georgia survey 1927–8	North side of South Georgia 1930–1	South side of South Georgia 1928–9	South Georgia survey 1928–9
	Nov.	Dec.–Jan.	Jan.–Feb.	Feb.–Mar.	March	April	Sept.
Warm-water species							
(*a*) *Euphausia vallentini*	—	—	—	0·02	—	—	1·33
(*b*) *Eucalanus* sp.	51·1	14·4	—	—	—	—	—
Candacia sp.	31·7	—	4·17	4·00	—	—	1·50
Heterorhabdus sp.	5·71	—	—	17·0	—	—	2·56
Euphausia triacantha	2·14	1·08	52·9	17·1	12·0	0·67	3·80
Calanus simillimus	101	188	372	340	—	287	26·7
Pleuromamma robusta	72·7	119	387	106	16·0	21·3	112
(*c*) Chaetognatha	937	160	547	242	135	266	2·61
Limacina balea	3·95	12·4	63·0	1780	—	116	66·1
Pareuchaeta sp.	31·1	549	413	166	213	35·0	2·67
Parathemisto gaudichaudi	18·8	136	597	27·3	91·0	103	3·91
Euphausia frigida	128	208	1200	258	673	233	181
Cold-water species							
(*g*) *Euphausia superba*	3260	29·8	1160	720	1850	7·60	278
Cleodora sulcata	1·57	1·09	0·05	0·24	—	—	0·19
Salpa fusiformis f. *aspera*	7·14	500	0·65	6·53	90·0	0·20	1·11
Tomopteris (large)	1·05	1·67	0·57	0·29	0·60	—	0·14
Tomopteris (small)	7·28	2·85	0·46	0·46	0·40	—	0·51
Metridia gerlachei	372	101	12·5	106	194	81·1	12·3
Clione antarctica	3·41	3·81	0·16	0·04	—	—	2·14
Limacina helicina	77·3	31·5	—	0·09	—	—	1·29
Pyrostephos vanhöffeni	—	0·62	—	0·27	22·4	—	0·29
(*h*) *Sibogita borchgrevinki*	0·14	0·02	—	—	—	—	—
Dimophyes arctica	5·09	0·08	—	—	0·02	—	—
Vanadis antarctica	0·09	0·02	0·02	—	0·60	—	—
Diphyes antarctica	0·37	—	—	—	—	—	—
Eusirus antarcticus	0·45	—	—	—	—	—	—
Auricularia antarctica	—	—	—	—	—	—	—
Haloptilus ocellatus	0·93	—	—	—	—	—	—
Neritic species							
Antarctomysis sp.	54·2	36·1	175	22·7	—	3·75	6·57

It will be seen that the November survey of 1930–1 differs from the others in that it has representatives of all species but one of the very coldest groups (*h*), and it must be remembered that these species never occur except in small numbers, and the mere presence of one of them in a sample is of some significance. The moderately "cold" species also (group (*g*)) are on the whole better represented in this survey than in the others, *Limacina helicina* and *Metridia* being specially numerous. Of the warm-water species *Eucalanus*, *Candacia* and the Chaetognatha are also strongly represented, but *Euphausia triacantha*, *Calanus simillimus*, *Pleuromamma*, *Limacina balea*, *Pareuchaeta*, *Parathemisto*, and *Euphausia frigida* are all in comparatively small numbers. It can be said in fact that in spite of the prominence of one or two warm-water species, this November survey was characterized by a much "colder" plankton than any of the other groups of stations.

During the survey of 1928–9 taken in December and January three of the very coldest group were present and the moderately "cold" species were well represented, notably *Salpa*, *Tomopteris* and *Clione*. Of the warm-water species *Candacia* and *Heterorhabdus* were absent, *Euphausia triacantha* and the Chaetognatha were scarce; but there was an increase in the number of *Calanus simillimus*, *Pleuromamma*, *Limacina balea*, *Parathemisto* and *Euphausia frigida*, and *Pareuchaeta* was more numerous than at any other time.

During the survey of 1929–30 in January and February only one of the coldest group was taken, a single specimen of *Vanadis* at St. 336, and the other "cold" species were very poorly represented. Of the warm-water species *Euphausia triacantha*, *Calanus simillimus*, *Pleuromamma*, *Parathemisto*, and *Euphausia frigida* were more numerous than at any other time (though it must be remembered that the plankton as a whole was very abundant during this survey) and the Chaetognatha, *Limacina balea*, and *Pareuchaeta* were also prominent.

The survey of 1927–8 in February and March was also characterized by a warm-water plankton. None of the "coldest" group was taken, and with the exception of *Metridia* the moderately "cold" species were all scarce. Among the warm-water species the presence of the sub-Antarctic species, *Euphausia vallentini*, is specially significant and although the plankton as a whole was not very rich *Heterorhabdus* and *Limacina balea* here reached their maxima and *Calanus simillimus* and *Euphausia frigida* were both relatively numerous.

At the stations taken in March 1930–1 the plankton population was again of a colder type, in which two of the very cold-water species are present and *Pyrostephos*, *Metridia* and *Salpa* are strongly represented. There is support for the "warm" group, however, in *Pareuchaeta*, *Parathemisto* and *Euphausia frigida*, whose numbers are large in proportion to the total amount of plankton.

At the stations taken in April 1928–9, hardly any colder water species were represented. Of the warm-water species *Eucalanus*, *Candacia* and *Heterorhabdus* were absent, but *Calanus simillimus*, *Limacina balea* and *Parathemisto* were present in quite large numbers.

Finally on the winter survey of September 1928, although the temperature of the water was below 0° C. at all stations and colder than at any other group of stations around South Georgia, none of the "coldest" species was taken and all the warm-water species except *Eucalanus* were present. *Euphausia vallentini* indeed was better represented than during the 1927–8 survey.

The conclusion to be derived from these facts is that, if the stations taken in March 1930–1 are excepted, the order of the groups of stations according to the months in which they were taken is also the order of "coldness" of the plankton population. Thus the November survey had much the "coldest" plankton. Next comes the December–January survey with still a distinct cold-water element, then the January–February survey with a warm-water plankton, and then the February–March survey with a similar plankton but with the sub-Antarctic *E. vallentini* and no *Vanadis*. There is no doubt about the order of "coldness" of these four surveys, and although we are dealing with four successive years it is highly probable that as the summer advances the South Georgia plankton becomes "warmer and warmer". The April stations and the September survey reveal perhaps the "warmest" plankton of all. The cold-water species taken in March 1930–1 can be explained by the fact that that season was an exceptionally cold one in which the pack-ice remained for a long time far north of its usual limits. Whether the November plankton around South Georgia normally has quite such a strong element of cold-water species as it did in 1930–1 is doubtful, but at all events the evidence leaves no reasonable doubt: (i) that in the South Georgia plankton the cold-water species are most strongly represented in the spring, and that as the summer advances they are reduced and the warm-water species gain ground, and that the warm-water plankton continues right through the winter; (ii) that an abnormally cold summer results in a "colder" plankton which however still becomes "warmer" as the summer passes.

There is evidence to show that changes of the same kind take place in other parts of the Antarctic water, and it will be convenient first to take the eastern part of the area covered by stations taken in 1927–31.

THE SOUTH SANDWICH AND WEDDELL SEA REGION

Table V shows, for various groups of stations in this region, the average number per haul of the warm- and cold-water species. The species grouped under (*d*), (*e*), and (*f*) in Table III, p. 107, and the neritic species *Antarctomysis* and *Euphausia crystallorophias*, are omitted.

In the 1927–8 season no cruise was made to the east or south-east of South Georgia, but in September and October 1928–9 the 'William Scoresby' took a number of stations along the edge of the pack-ice which lay about 100 miles to the east of the island (see Fig. 11). Two of the stations (WS 287 and 288) were taken late in September before the winter survey of the South Georgia area had been finished. The ship then returned to South Georgia, completed the survey and then carried out the other ice-edge stations early in October (WS 298–310). We have seen that during this winter survey the plankton was of a clearly warm-water type (see Table IV, September 1928–9, p. 122). The short journey to the ice, however, brought the ship into an entirely different plankton. Column 1 in Table V shows that there was here a typically cold-water plankton in which *Sibogita*, *Dimophyes*, *Diphyes* and *Auricularia* were all present, while the warm-water species were much reduced. The state of affairs is illustrated in Fig. 40.

Table V. *Warm- and cold-water species in the South Sandwich and Weddell regions*

Season	1928–9	1929–30			1930–1				
Month	Sept.–Oct.	Feb.	Mar.	Mar.	Dec.	Jan.–Feb.	Jan.–Feb.	Feb.	Feb.
Station	WS 287–8 and WS 298–310	360–2	365–9	372–3	528–33	WS 536–43 and WS 555–61	WS 544–51	618–23	626–9
Number of samples ...	15	3	2	2	5	10	7	6	4
Column number ...	1	2	3	4	5	6	7	8	9
Warm-water species									
(*a*) *Euphausia vallentini*	—	—	—	—	—	—	—	—	—
(*b*) *Eucalanus* sp.	—	—	—	—	—	—	—	—	—
Candacia sp.	—	—	—	25·0	—	0·71	—	—	—
Heterorhabdus sp.	1·00	200	—	—	—	—	—	—	—
Euphausia triacantha	12·0	0·50	—	—	0·20	—	—	—	—
Calanus simillimus	—	—	—	105	—	0·71	—	—	—
Pleuromamma robusta	—	200	—	—	—	23·9	—	7·00	5·00
(*c*) Chaetognatha	2·17	376	200	15·0	271	160	224	107	58·2
Limacina balea	5·83	25·0	—	—	—	39·3	—	—	3·33
Pareuchaeta sp.	—	800	—	400	24·0	17·1	55·0	29·0	25·0
Parathemisto gaudichaudi	0·46	46·7	—	51·0	9·00	28·3	—	59·6	14·2
Euphausia frigida	30·0	1800	3·33	627	39·8	379	—	34·5	65·5
Cold-water species									
(*g*) *Euphausia superba*	1580	4·33	1770	710	4·80	15,545	17·9	1243	3518
Cleodora sulcata	85·0	1·00	4·50	7·50	9·00	24·6	9·75	5·00	4·00
Salpa fusiformis aspera	0·40	6·00	1·00	4·50	69·0	1·71	8·67	28·0	—
Tomopteris sp. (large)	0·53	0·33	0·67	0·50	2·00	2·00	1·43	1·16	1·25
Tomopteris sp. (small)	6·53	—	0·50	—	6·80	5·10	12·3	0·14	23·3
Metridia gerlachei	—	650	25·0	—	1652	1020	890	348	1155
Clione antarctica	1·33	—	—	—	2·60	6·10	1·00	—	3·50
Limacina helicina	7·60	1·33	10·5	—	40·2	15·1	47·3	—	11·0
Pyrostephos vanhöffeni	—	—	22·0	—	46·8	218	12·0	—	—
(*h*) *Sibogita borchgrevinki*	0·13	—	—	—	0·40	0·10	0·57	—	—
Dimophyes arctica	4·33	—	7·00	—	4·60	28·3	26·3	—	—
Vanadis antarctica	—	0·33	—	—	0·40	0·20	0·57	—	—
Diphyes antarctica	2·93	—	1·00	—	3·60	6·00	10·4	—	7·00
Eusirus antarcticus	—	—	0·50	—	1·60	1·44	—	—	—
Auricularia antarctica	0·33	—	—	—	0·20	1·00	28·3	—	—
Haloptilus ocellatus	—	—	—	—	—	2·00	306	—	—

In the 1929–30 season the 'Discovery II' visited the South Sandwich Islands during the end of February and the beginning of March, just after the South Georgia survey. We have seen that this survey revealed a warm-water plankton, and at the first three stations on the way to the South Sandwich Islands (Sts. 360–2, Fig. 12) the warm-water species were still predominant (see Fig. 41 and column 2 in Table V). At St. 365, however, *Pyrostephos*, *Dimophyes* and *Eusirus* make their appearance, and at St. 369 *Pyrostephos* and *Diphyes antarctica* were taken. At St. 368, the only other N 100 B station taken at this time, the sample could not be properly analysed owing to a large catch of *Euphausia*

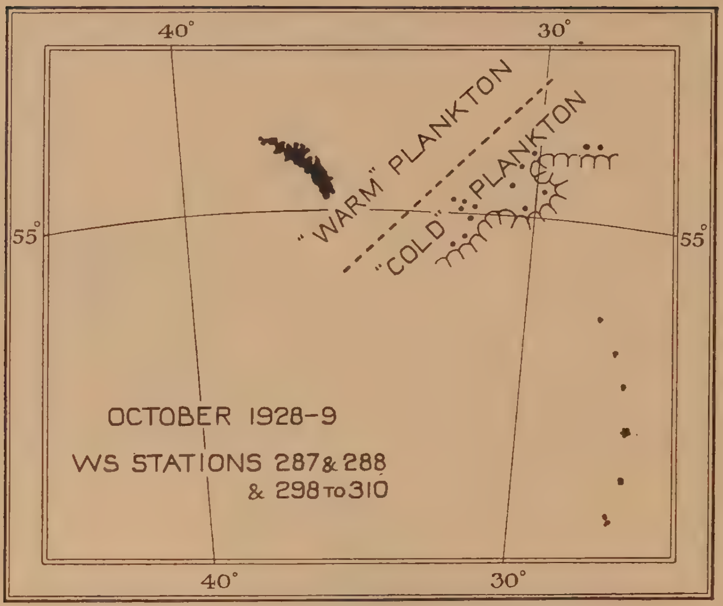

Fig. 40. Distribution of warm- and cold-water plankton between South Georgia and the South Sandwich Islands. The edge of the pack-ice is indicated.

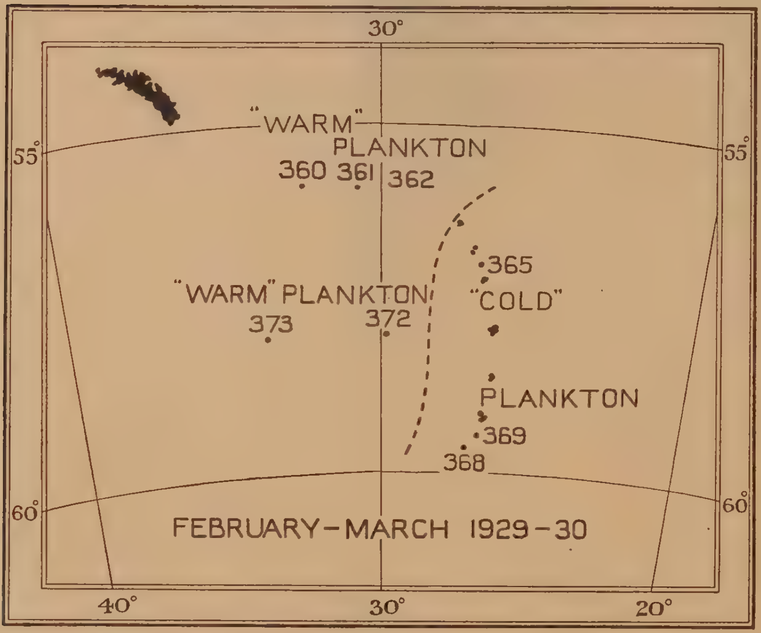

Fig. 41. Distribution of warm- and cold-water plankton between South Georgia and the South Sandwich Islands. No pack-ice was seen.

superba. Column 3 in Table V, however, shows how greatly the warm-water species were reduced at Sts. 365 and 369. On leaving the South Sandwich Islands the ship started a line of stations to the west (Sts. 372, 373, etc.) and here we see the plankton was again of the warm type. Column 4 in the table shows a very striking contrast between Sts. 365 and 369, and Sts. 372 and 373. Fig. 41 shows the relative positions of the "warm" and "cold" plankton.

In the 1930–1 season a number of stations were taken to the east and south-east of South Georgia (see Fig. 14, p. 82). In October the 'Discovery II' sailed from Capetown to South Georgia *via* Bouvet Island and the journey from Bouvet Island to South Georgia was mainly along or through the outskirts of the pack-ice (see Fig. 42). As these stations are in the form of an extended line they are not separated into groups and shown in Table V. The stations at the east end of this line had not perhaps a very "cold" plankton, but *Diphyes antarctica* was present at all of them, *Dimophyes* was taken at St. 453, and *Haloptilus ocellatus* appeared at St. 460. At Sts. 462–9 the plankton was of a warmer type. There was a single specimen of *Eusirus* at St. 466 and of *Auricularia* at St. 469, but at all of these stations there were large numbers of *Limacina balea*, reaching a maximum at St. 466, and comparatively abundant *Euphausia frigida* (both warm-water species). At St. 470 there were three specimens of *Eusirus* and at Sts. 471 and 472 *Diphyes antarctica* reappeared and the numbers of *L. balea* and *E. frigida* became suddenly reduced. When the ship reached South Georgia the November survey was begun, and as already noted revealed here a very cold-water plankton. It seems therefore that in the early summer of 1930–1 there was a cold-water plankton in the neighbourhood of Bouvet Island and South Georgia, but between the two a rather "warmer" plankton.

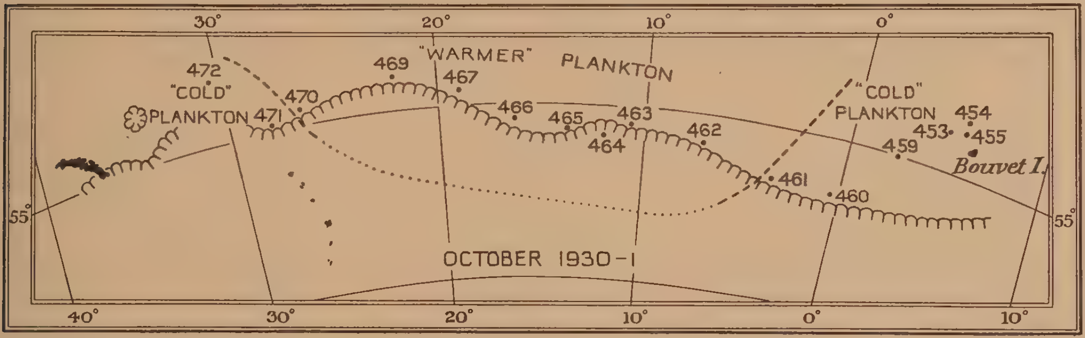

Fig. 42. Distribution of warm- and cold-water plankton between South Georgia and Bouvet Island. The edge of the pack-ice is indicated.

When the ship reached South Georgia the pack-ice was lying close up to the island, but at the end of November, when the survey was finished, the ice-edge had receded some way to the south-east. In December the 'Discovery II' sailed in this direction, and, on meeting the ice, followed its edge in a south-westerly direction, taking Sts. 528–33 in the positions shown in Fig. 43. Here the constitution of the plankton was still very "cold" (see column 5 in Table V, p. 125), even more so than around South Georgia in November. Of the warmest group only *Euphausia triacantha* was represented, and all the coldest species were present except *Haloptilus ocellatus*.

Late in January the 'William Scoresby' also sailed south-eastwards from South Georgia and found that the ice had retreated to the northern end of the Sandwich group. This ice was skirted to the eastward and was found to fall away to the south and disappear. The ship steamed southwards for some 600 miles in open water and finally reached more ice in the eastern part of the Weddell Sea (Fig. 44). At the stations taken off the ice around the South Sandwich Islands the same "cold" plankton was taken, though some warm-water species, particularly *Euphausia frigida*, were well represented (see Table V, column 6). Farther south (WS 544–51) the cold-water species increased and the warm-water species almost vanished (see Table V, column 7). *Haloptilus ocellatus* was taken here in exceptional numbers. These last stations were taken in an area which is probably covered with pack-ice during the greater part of the year.

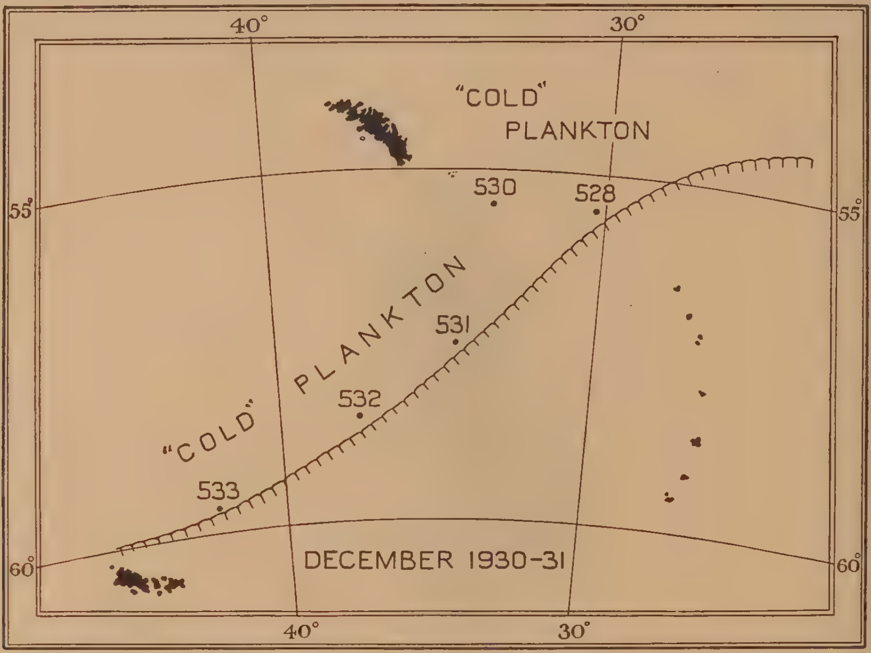

Fig. 43. Distribution of warm- and cold-water plankton in the eastern part of the Scotia Sea. The edge of the pack-ice is indicated.

In February the 'Discovery II' returned to the South Sandwich region, working stations along the ice-edge between the South Orkney Islands and the Sandwich group. These stations (618–29) are shown in Fig. 45. The ice here had retreated very little since December (Fig. 43), but the plankton had changed to a much warmer type. None of the very "cold" group was present but such warm-water species as *Pareuchaeta*, *Pleuromamma*, and *Euphausia frigida* were included in the catches. As the ship approached the South Sandwich Islands, however, signs of a "colder" plankton appeared. *Vanadis* occurred at St. 624, and *Diphyes antarctica* at Sts. 625, 626, 628 and 629. At the same time smaller numbers of *Pareuchaeta* and *Pleuromamma* were taken (see Fig. 45 and

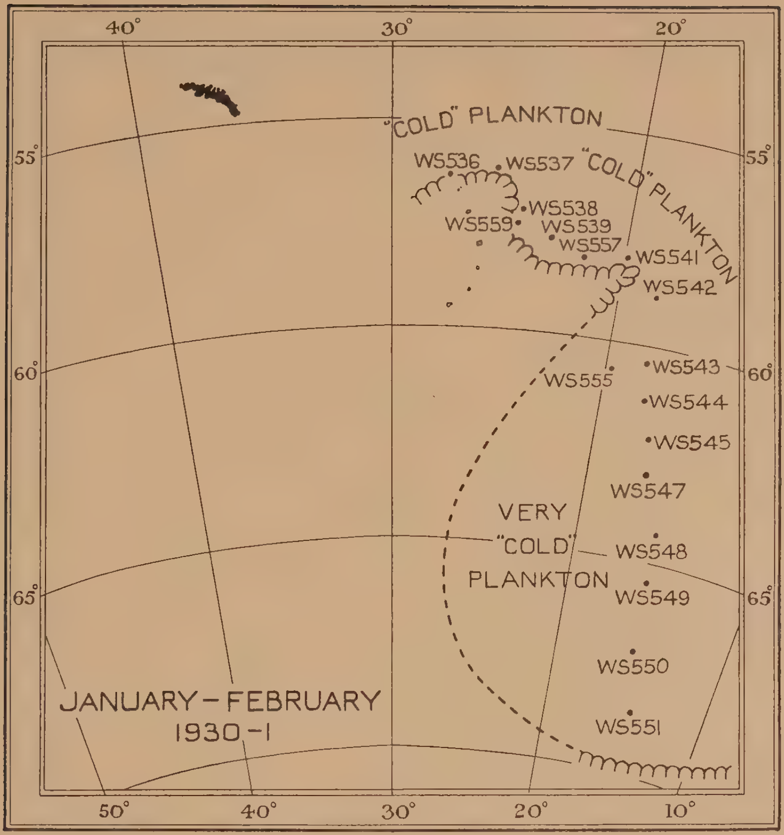

Fig. 44. Distribution of warm- and cold-water plankton near the South Sandwich Islands and in the eastern part of the Weddell Sea. The observed and conjectured positions of the ice edge are indicated.

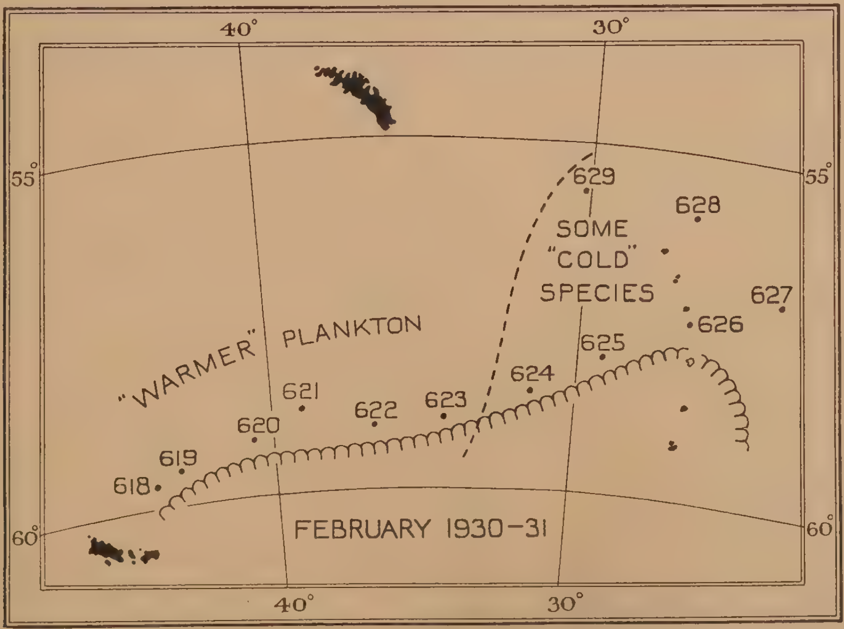

Fig. 45. Distribution of warm- and cold-water plankton in the eastern part of the Scotia Sea. The edge of the pack-ice is indicated.

Table V, column 8). The plankton here, however, although it contained an element of cold-water species, was not nearly so "cold" as it was in the same region earlier in the season. The conditions were in fact very similar to those which obtained about February and March 1929–30 (Fig. 41).

It has been seen that the evidence strongly suggests that around South Georgia the cold-water species are prominent in spring, but become reduced as the summer advances, and we now have clear evidence that in the 1930–1 season, in the area roughly between the South Sandwich and South Orkney Islands, a "cold" plankton in December gave way to a comparatively "warm" plankton in February (compare Figs. 43 and 45). There is every reason to suppose that this is a normal process. 1930–1 is the only single season in which the plankton distribution can be compared in several different months, but the conditions in October 1928–9 and February–March 1929–30 fall into place very well. The 1928–9 season was not so cold as the 1930–1 season, the ice did not reach quite so far north in October, and the area of the South Georgia survey was not invaded by the "cold" plankton, which, however, came very near to it. The 1929–30 season was a mild one and there was no sign of ice round the South Sandwich Islands, but the conditions in February–March were very similar to those in February 1930–1, except that the cold-water species had retreated farther to the south-east.

It is difficult to decide exactly what connection exists between the pack-ice and the presence of the very cold-water species (group (*h*) in Table III, p. 107). They are rarely if ever found except close to the ice or in places in which there has recently been ice. On the other hand the presence of ice does not necessarily entail the presence of cold-water plankton.

Fig. 46 shows the changes in the position of the pack-ice during the 1930–1 season, and its tendency to hang around the South Orkney and South Sandwich Islands while farther to the east the sea becomes clear of pack-ice for hundreds of miles to the southward. In Fig. 47 the boundaries between the warm- and cold-water plankton shown in Figs. 40, 41, 42 and 45 are superimposed on one chart. This shows again how the cold-water plankton retreats to the south-east of South Georgia. It will be seen that westward from the South Sandwich Islands a warmer plankton is always found, and there is evidence of a tendency towards a warmer plankton also to the east of the islands (see Fig. 42). It seems in fact that around the South Sandwich Islands there is a tongue of cold-water plankton reaching up from the south.

The cyclonic circulation in the Weddell Sea, and the cold water which flows out towards the South Orkney and South Sandwich Islands is responsible for the persistent ice and the cold-water plankton in this region, and it is possible that the ridge of the South Sandwich chain temporarily deflects the current towards the north, carrying the cold-water species up in the tongue mentioned above.

The presence of cold-water species near Bouvet Island suggests that there might be another cyclonic system farther to the east, and Wüst (1928) has published a chart of current systems in the Atlantic which does in fact show such a system. Its centre is given as about 60° S, 30° E, and its orbit just embraces the stations near Bouvet Island

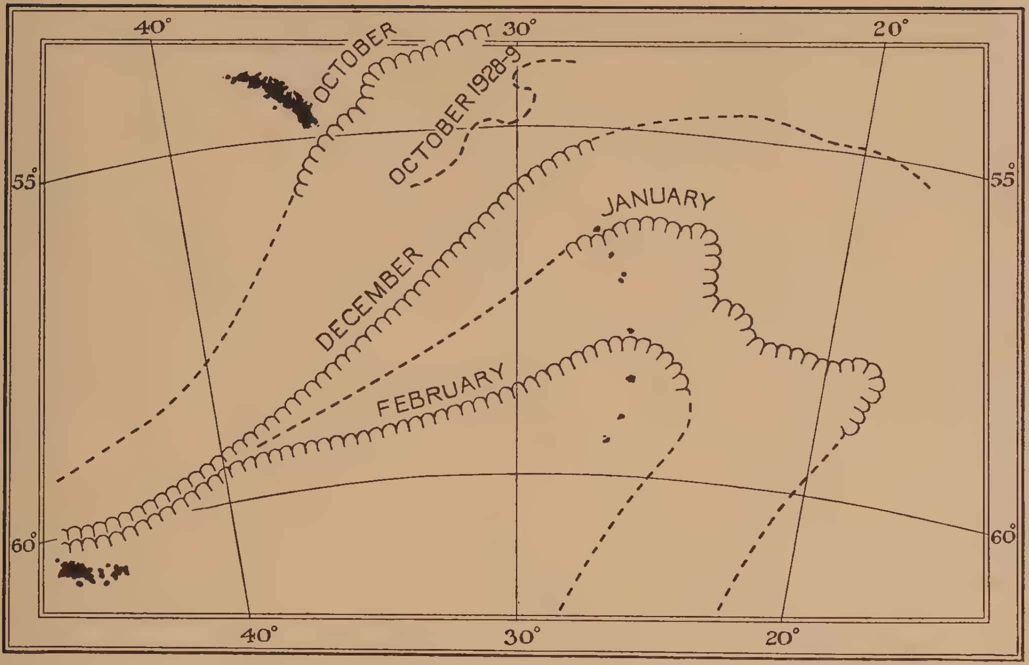

Fig. 46. Changes in the position of the ice edge during the season 1930–1. Note the recession of the ice as the season advances. The position of the ice in October 1928–9 is shown for comparison.

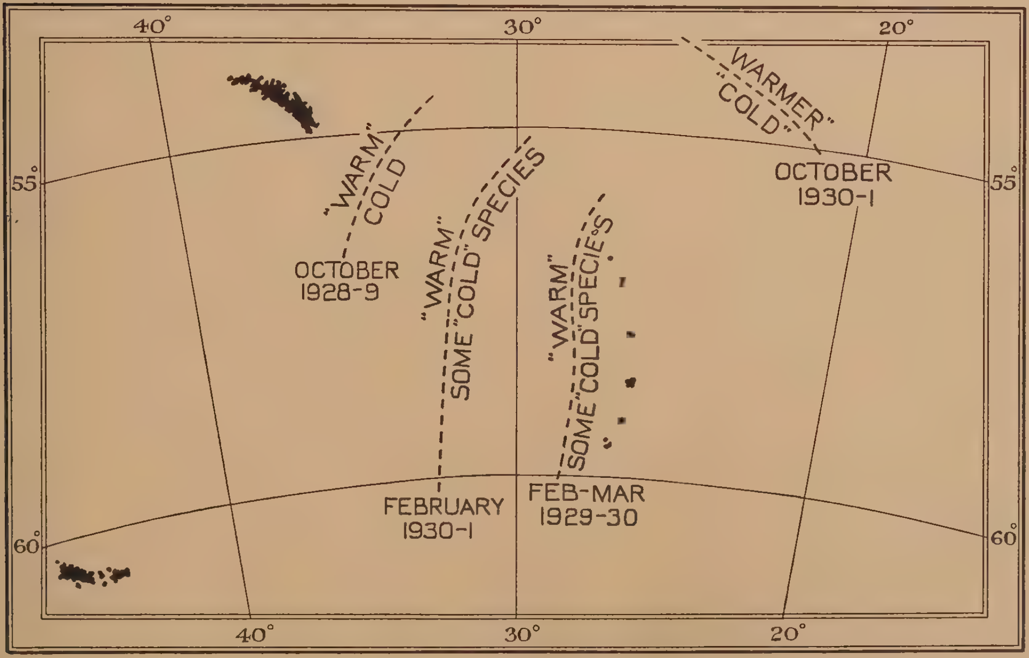

Fig. 47 Relative positions of warm- and cold-water plankton at different times in the vicinity of South Georgia and the South Sandwich Islands.

at which the cold species were found. I understand, however, that in the light of more recent work by the 'Discovery II' it is to be doubted whether there is actually a cyclonic movement here in any way comparable in importance to that of the Weddell Sea.

THE ORKNEY-SHETLAND REGION

Under this heading are included all the stations taken in the area of scarce plankton around the South Orkney and South Shetland Islands and the lines of intensive stations in the Bransfield Strait. In Table VI the separate groups of stations are arranged in order of the months in which they were taken, as in Table IV on p. 122, but the Bransfield Strait stations are dealt with separately. Many of the warm-water species (groups (*a*) and (*b*) in Table III, p. 107) do not occur at all in this region and are therefore omitted from the table.

Table VI. *Warm- and cold-water species in the Orkney–Shetland region*

	Bransfield Strait				South Orkneys to South Shetlands					
Station numbers	WS 476–93	542–55	607–12	WS 382–99	WS 474	534–41	613–15	WS 380, 381	637–44	WS 202
Number of samples ...	18	14	4	18	1	7	3	2	8	1
Year	1929–30	1930–1	1930–1	1928–9	1929–30	1930–1	1930–1	1928–9	1930–1	1927–8
Month	Nov.	Dec.	Feb.	Feb.	Nov.	Dec.	Feb.	Feb.	Mar.	April
Column number	1	2	3	4	5	6	7	8	9	10
Warm-water species										
(*c*) Chaetognatha	7·33	4·86	—	0·33	—	100	21·0	0·50	—	—
Limacina balea	1·10	—	—	—	—	—	—	—	—	—
Pareuchaeta sp.	—	1·20	—	—	—	1·25	2·33	—	56·0	120
Parathemisto gaudichaudi	—	0·07	31·0	15·0	—	0·43	5·67	3·50	11·4	350
Euphausia frigida	—	2·20	32·0	27·7	54·0	14·2	23·0	16·0	14·0	18·0
Cold-water species										
(*g*) *Euphausia superba*	170	12·2	191	429	—	964	2·00	71·0	406	228
Cleodora sulcata	—	0·20	—	—	—	0·50	—	—	—	—
Salpa fusiformis f. *aspera*	—	0·80	1·00	—	—	42·0	191	437	177	3·00
Tomopteris sp. (large)	—	—	—	—	8·00	—	—	—	—	1·00
Tomopteris sp. (small)	0·17	1·07	0·25	—	—	0·43	—	—	0·29	—
Metridia gerlachei	4·71	14·2	—	138	—	50·2	155	11·5	1580	3344
Clione antarctica	0·70	0·57	1·00	—	1·00	0·40	0·33	—	—	—
Limacina helicina	5·78	3·43	—	0·12	6·00	7·29	—	0·50	0·14	—
Pyrostephos vanhöffeni	—	—	—	—	—	—	—	—	—	—
(*h*) *Sibogita borchgrevinki*	—	0·07	—	—	—	0·14	—	—	—	—
Dimophyes arctica	0·78	0·21	—	—	—	1·29	1·33	—	—	—
Vanadis antarctica	—	—	0·25	—	—	—	—	—	0·12	—
Diphyes antarctica	0·28	0·29	—	—	—	0·43	0·67	—	0·12	—
Eusirus antarcticus	—	0·21	—	—	—	0·25	—	—	—	—
Auricularia antarctica	0·17	0·86	0·25	—	1·00	—	0·33	—	0·14	—
Haloptilus ocellatus	—	—	—	—	—	1·43	3·00	—	—	—

The figures here emphasize the relative "coldness" of the 1930–1 plankton rather more clearly than the reduction of cold-water species as the summer goes on. However, if the 1930–1 season is considered separately it will be seen that in the Bransfield Strait the cold-water species were much more strongly represented in December than in February, and that in the latter month, although the Chaetognatha and *Pareuchaeta* were not taken, *Parathemisto* and *Euphausia frigida* had increased very greatly (see columns 2 and 3). The surveys in the Bransfield Strait in 1929–30 and 1928–9 show a marked contrast. At the former, which was in November, plenty of "cold" species were taken, and *Limacina balea* and some Chaetognatha were the only warm-water species. At the latter, which was in February, none of the very "cold" species was present and only one or two of the moderately "cold", while *Parathemisto* and *Euphausia frigida* appeared in quite large numbers for this locality (see columns 1 and 4). It may be mentioned here that the Chaetognatha, as a group, are not to be relied on as a warm element in the plankton, especially in such places as this where *Eukrohnia hamata* is not necessarily the dominant species.

In the region between the South Shetlands and the South Orkneys there was a large element of cold-water species in December 1930–1. In February in the same season there was little, if any, diminution in the very cold-water species, but there were fewer of the moderately "cold" group and more of the warm-water species. In March there were definitely fewer of the "coldest" species, and the warm-water species on the whole were stronger than in February (see columns 6, 7 and 9). Single stations are unreliable, but the one taken in November 1929–30 (column 5) suggests a "colder" plankton than was found in February 1928–9 or April 1927–8.

Table VI provides an interesting example of the unusual coldness of the 1930–1 season. The catches in February of this season can be compared with those of February 1928–9 both in the Bransfield Strait and farther east (columns 3, 4, and 7, 8). It will be seen that a much "colder" plankton was present in 1930–1 than in 1928–9.

THE BELLINGSHAUSEN SEA

The Bellingshausen Sea has been visited only twice, each time in the middle of the summer, so that we have not the material for a comparison of the conditions in different months, but there is some interest in a comparison between the plankton taken by the 'William Scoresby' in 1929–30 and the 'Discovery II' in 1930–1. Table VII shows the average number of warm- and cold-water species taken during these two cruises. It has been seen in a previous section that a much richer plankton was taken in the more westerly part of the Bellingshausen Sea than in the eastern part, and these further stations are therefore treated separately in the table.

The principal conclusion to be drawn from these figures is that, at any rate in the western Bellingshausen Sea, the plankton of 1930–1 was not of a colder type than that of 1929–30, although everywhere to the west of the South Shetlands exceptionally cold conditions were met with in the former season, while in the latter season the conditions were unusually mild. The dates on which the 'William Scoresby' took observations in the western Bellingshausen Sea in 1929–30 were about three weeks later than those of the corresponding stations of the 'Discovery II' in 1930–1, and yet at the former the *very* "cold" species were on the whole more numerous than at the latter. It is true that in the eastern part of the Bellingshausen Sea a slightly "colder" plankton was taken in 1930–1 than in 1929–30, but the difference is not nearly so great here as it was for instance in the region between the South Shetland and South Sandwich Islands. The figures, in fact, seem to suggest that if in any season exceptionally cold or mild conditions are experienced on the east side of the Drake Passage, the same conditions do not necessarily prevail on the west side. More evidence is needed, however, before the point can be definitely settled.

Table VII. *Warm- and cold-water species in the Bellingshausen Sea*

Area	Eastern Bellingshausen		Western Bellingshausen	
Season	1929–30	1930–1	1929–30	1930–1
Month	Jan.–Feb.	Dec.–Jan.	Jan.	Jan.
Station numbers ...	WS 496–501 and WS 508–17	556–62 and 580–603	WS 502–5	563–79
Number of samples ...	14	29	4	17
Warm-water species				
(*c*) Chaetognatha	14·5	4·35	1223	182
Limacina balea	—	—	—	—
Pareuchaeta sp.	18·8	4·54	128	22·2
Parathemisto gaudichaudi	32·8	1·34	0·73	—
Euphausia frigida	—	0·75	—	4·00
Cold-water species				
(*g*) *Euphausia superba*	12·1	3·86	2·50	6·30
Cleodora sulcata	0·17	0·29	5·00	1·12
Salpa fusiformis f. *aspera*	2·00	13·6	—	84·5
Tomopteris sp. (large)	0·07	0·31	4·00	1·00
Tomopteris sp. (small)	0·36	1·83	45·2	16·6
Metridia gerlachei	150	47·7	400	70·5
Clione antarctica	0·14	0·62	10·5	3·87
Limacina helicina	12·1	7·93	51·5	89·9
Pyrostephos vanhöffeni	20·2	2·34	55·2	2·94
(*h*) *Sibogita borchgrevinki*	—	—	0·25	0·12
Dimophyes arctica	—	0·03	4·00	15·2
Vanadis antarctica	—	0·03	1·00	0·41
Diphyes antarctica	—	0·03	1·50	0·94
Eusirus antarcticus	0·33	0·81	0·50	1·00
Auricularia antarctica	0·21	0·34	5·00	0·53
Haloptilus ocellatus	—	0·10	176	2·35

THE NORTHERN ANTARCTIC REGION

This heading refers to the belt of warmer water lying between the Antarctic convergence and South Georgia and the South Shetlands. Most of the lines of stations crossing this zone run between the Falkland Islands and South Georgia, some cross the Drake Passage, and some more stations lie roughly between the South Orkney Islands and the Falkland Islands. There is sufficient material for an independent monthly comparison in two of the seasons, and the four seasons are therefore taken separately in

Table VIII. *Warm- and cold-water species in the outer Antarctic water*

Season	1927–8		1928–9					1929–30					1930–1		
Month	Feb.	Apr.	Aug.	Dec.	Feb.	Mar.	May	Nov.	Nov.	Mar.	Mar.	Apr.	Mar.	Mar.	Mar.
Station numbers	WS 140–2	WS 203, 204	WS 254–6	WS 314–16	WS 400–4	WS 413–16	WS 427–30	WS 464, 465	WS 469–73	WS 521–6	WS 527–9	378–84	633–6	646–9	656–9
Number of samples ...	3	2	3	3	5	4	4	2	5	6	3	4	4	3	4
Position of line	Falklands to South Georgia	South Orkneys to Falklands	Falklands to South Georgia	South Georgia to Falklands	Drake Passage	Falklands to South Georgia	South Georgia to Falklands	South Georgia to Falklands	Falklands to South Shetlands	Falklands to South Georgia	South Sandwich Islands to Burdwood Bank	Drake Passage	Falklands to South Orkneys	Drake Passage	Cape Horn to South Georgia
Column number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Warm-water species															
(*a*) *Euphausia vallentini*	—	10·5	1·50	?	0·50	?	Present	—	—	—	?	—	590	—	?
(*b*) *Eucalanus* sp.	—	—	—	64·0	—	Present	8·00	64·0	10·7	—	?	—	—	—	—
Candacia sp.	—	4·00	8·00	?	—	?	?	—	Present	—	?	—	20·0	—	?
Heterorhabdus sp.	—	4·00	7·00	?	0·50	?	24·0	16·0	—	—	?	50·0	20·0	5·00	?
Euphausia triacantha	7·00	19·5	5·50	?	23·0	Present	Present	0·50	—	6·00	?	29·5	42·0	2·00	?
Calanus simillimus	—	86·0	—	192	80·0	208	252	8·00	6·67	1040	Present	0·67	440	—	Present
Pleuromamma robusta	16·0	28·0	116	?	129	?	Present	64·0	8·00	256	?	40·0	65·0	10·0	?
(*c*) Chaetognatha	803	1148	1·00	256	192	284	784	865	515	262	Present	3601	1055	429	Present
Limacina balea	80,152	2720	13·0	Present	?	288	615	30·0	9·33	3707	Present	—	1400	—	Present
Pareuchaeta sp.	16·0	94·0	2·00	?	218	?	Present	80·0	—	224	?	355	500	40·0	?
Parathemisto gaudichaudi	170	17·5	3·67	932	40·8	93·5	243	97·5	45·8	154	78·3	120	37·7	7·33	12·0
Euphausia frigida	610	87·0	307	24·0	206	417	173	21·0	2·00	713	?	132	31·0	30·0	—
Cold-water species															
(*g*) *Euphausia superba*	—	—	16·0	—	—	2·00	3·00	1·50	—	—	287	2·00	—	2·33	607
Cleodora sulcata	—	—	0·50	—	—	?	—	—	—	1·50	?	—	—	—	—
Salpa fusiformis f. *aspera*	8·00	1·50	—	?	64·5	Present	?	6·50	—	1·00	Present	108	10·0	67·0	?
Tomopteris sp. (large)	—	—	0·33	0·67	—	—	—	0·50	1·00	0·33	1·33	0·25	—	0·33	—
Tomopteris sp. (small)	2·33	—	1·33	1·67	—	—	1·00	—	31·0	—	—	—	—	6·00	—
Metridia gerlachei	96·0	24·0	—	?	46·0	?	?	208	8·00	—	?	—	15·0	130	?
Clione antarctica	1·50	—	1·50	1·00	—	—	—	2·00	4·33	—	?	—	—	—	—
Limacina helicina	Present	—	—	34·7	—	—	—	45·5	21·4	—	—	—	—	—	—
Pyrostephos vanhöffeni	2·00	—	—	12·3	—	—	—	—	18·2	—	—	—	—	—	—
(*h*) *Sibogita borchgrevinki*	—	—	—	—	—	—	—	—	0·20	—	0·33	—	—	0·33	—
Dimophyes arctica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vanadis antarctica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Diphyes antarctica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Eusirus antarcticus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Auricularia antarctica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Haloptilus ocellatus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table VIII. This table shows the average number of warm- and cold-water species per haul for each line of stations. On some of the lines none of the stations was taken in the middle of the night, and consequently the diurnal variations of some species prevent a reliable estimate of their numbers. A query is inserted where a species is absent but might have been taken if there had been a haul between the appropriate hours at night, and "Present" is inserted where a few were actually taken but where a larger number might be expected in a night haul.

In these waters the moderately "cold" species (group (*g*)) play a part corresponding to that of the very "cold" group in the high latitudes. As in other regions, the figures here show a diminution in the proportion of cold-water species as the summer advances. A glance at columns 1 and 2 shows a much "warmer" plankton in April than in February 1927–8. In the 1928–9 season the warm-water species were quite well represented at the August stations, as they were in September off South Georgia, and the "coldest" plankton is found in December, i.e. early in the summer. In February, March and May there is a general reduction of cold-water species and an increase in nearly all the warm-water species. In the 1929–30 season the "coldest" plankton, as we should expect, is taken in November. The cold-water species mostly disappear in March and April, though a specimen of *Sibogita* unaccountably appears in March. Of the warm-water species *Heterorhabdus* sp., *Euphausia triacantha*, *Pleuromamma*, *Pareuchaeta*, *Parathemisto* and *Euphausia frigida* increase towards the end of the season. Others are irregular and *Eucalanus* is more plentiful in November. In the 1930–1 season stations in this area were taken only in March, but it will be seen that the catches include slightly more cold-water species than those of March 1929–30 and 1928–9. We should expect this in view of the fact that the 1930–1 season was a specially cold one.

It is now clear that over the area covered by the investigations, wherever it is possible to compare observations taken at different times of year, the plankton at a given point has a larger element of cold-water species at the beginning of the summer (November and December) than it has later on. It seems also certain that in unusually cold seasons, such as 1930–1, the cold-water species have a tendency to persist in relatively low latitudes for a longer period than they would in a normal season. The stations taken in August and September 1928, suggest that the relatively "warm" plankton, found at the end of the summer, persists throughout the winter. There was at that time a thin plankton composed only of the warm-water species in proportions resembling those of the previous season. It is highly probable that the plankton undergoes little change from March or April or through the winter, remaining as a slowly diminishing population until the spring, when there is an invasion of cold-water species and a development of the rich summer plankton. There seems to be an increase in the proportion of warm-water species as the summer goes on, but this is not quite so clearly defined as the disappearance of the cold-water species.

The gradual change from a cold- towards a warm-water plankton does not of course imply a southerly drift of the Antarctic surface water during the summer. It is quite probable that the cold-water species generally develop earlier in the summer than the warm-water species and become replaced by the latter as time goes on.

It is difficult to say what connection may exist between the plankton population and the movements of the pack-ice. It is generally understood that the ice-edge reaches its most northerly limit at the end of winter or in the spring. This is also the time at which the plankton contains the maximum proportion of cold-water species. The distribution of certain species, also, seems to be limited to regions within the range of the pack-ice, for the northern limit of *Diphyes antarctica*, *Eusirus* and some other species typical of the coldest water coincides, at least approximately, with the northern limit of the pack-ice.

It is worth mentioning, as a matter of separate interest, that a curious red colouring has been noticed in several species taken off the ice-edge in certain places, particularly in the eastern part of the Weddell Sea and to the south-west of Bouvet Island. The catches here included large numbers of *Calanus propinquus* in most of which the antennae were of a bright red colour. The red-banded variety of *Tomopteris carpenteri* mentioned on p. 99 also occurred in some of these samples, and a small red Amphipod, at present unidentified, was not uncommon. The red antennae of the copepods often imparted a striking reddish appearance to the whole sample, especially when combined with other red species.

PLANKTON COMMUNITIES

Certain contrasts between the plankton of different regions have already been established. It has been seen for instance that certain groups of species are typical of the colder and others of the warmer waters. The chart shown in Fig. 21 (p. 105) indicates that the northern limit of some species and the southern limit of others lie in a belt running from the South Shetlands to South Georgia which coincides roughly with the junction of the Bellingshausen and Weddell Sea water. It has further been seen that in the coastal waters of the South Shetlands and South Orkney region the plankton has a characteristic which appears to be constant, namely the persistent scarcity of nearly all the species with which this paper is concerned (see Fig. 23, p. 110). On geographical grounds three main water masses can be distinguished. It will be seen from Fig. 1 that Graham Land and the South Shetlands divide the Weddell Sea from the Bellingshausen Sea in the higher latitudes, and leave a continuous outer belt of Antarctic water in the lower latitudes, which flows from west to east immediately south of the convergence.

In this section the plankton of the Weddell Sea, the Bellingshausen Sea, the outer belt and the area of scarce plankton around the South Orkney and South Shetland Islands are considered separately, but it will be remembered that between the plankton populations of the Weddell Sea and the outer belt there is a comparatively broad transition zone. The populations of these four areas are compared and an attempt is made further to subdivide them according to the nature of the populations. To do this it is necessary to examine separately all the important lines of stations.

THE WEDDELL SEA

A line of stations (WS 535–61) taken in the 1930–1 season gives a useful indication of the plankton conditions in the Weddell Sea water east of the South Sandwich Islands and, farther south, on the eastern side of the Weddell Sea itself (see Fig. 14). Table IX shows, for each station, the numbers of the ten most important species taken on this line, together with the total number of all species excluding those which tend to form shoals. Most of the stations were taken on the outward journey, but some were taken on the return, which was on very much the same course. The latter stations are inserted in the table in their proper positions relative to the others.

Table IX. *South Georgia to eastern Weddell Sea*

Date	January–February 1931									
Station	North WS 561	WS 535	WS 560	WS 536	WS 537	WS 538	WS 559	WS 539	WS 557	WS 541
Hour	21	22	21	22	01	13	21	22	08	12
Calanus acutus	3900	?	>780	7,400	—	?	18,000	35	3600	200
Rhincalanus gigas	1200	?	>260	1,200	—	?	—	250	*420*	*2000*
Euphausia superba	1	190,000	9	21	130	6000	2	9	11	114
Thysanoessa sp.	1200	?	94	200	730	?	600	2100	1200	*139*
Calanus propinquus	40	?	340	1,700	220	?	1,100	50	*180*	*2000*
Euphausia frigida	63	?	75	1,400	800	?	150	160	?	?
Parathemisto gaudichaudi	63	?	4	—	9	?	130	39	5	5
Metridia gerlachei	—	?	160	1,600	1200	?	4,000	160	*80*	?
Pleuromamma robusta	—	?	—	—	10	?	—	37	?	?
Haloptilus ocellatus	—	?	—	—	—	?	—	—	—	—
Total organisms (excluding shoaling species)	7400	?	2000	13,600	3000	?	24,000	3000	*5600*	5800

Date	January–February 1931									
Station	WS 542	WS 543	WS 555	WS 544	WS 545	WS 547	WS 548	WS 549	WS 550	South WS 551
Hour	22	14	23	20	14	22	13	22	10	20
Calanus acutus	?	6,300	1300	2000	1200	5700	3000	3800	4400	2600
Rhincalanus gigas	?	*5,400*	1100	280	?	40	*440*	80	*360*	460
Euphausia superba	5500	270	—	17	1	107	—	—	—	—
Thysanoessa sp.	?	*120*	100	136	*20*	86	*36*	41	*23*	150
Calanus propinquus	?	*960*	120	1600	*440*	1100	*1400*	520	*840*	660
Euphausia frigida	?	*45*	13	—	?	—	?	—	?	—
Parathemisto gaudichaudi	?	—	2	—	—	—	—	—	—	—
Metridia gerlachei	?	*400*	100	2200	*3100*	360	*320*	480	*440*	480
Pleuromamma robusta	?	?	100	?	?	—	?	—	?	—
Haloptilus ocellatus	?	—	20	80	240	—	520	360	480	460
Total organisms (excluding shoaling species)	?	*15,000*	3400	6800	*5500*	7400	*6100*	5700	*7200*	5700

Many of these stations were in high latitudes where there was little darkness at night and where there seems to be little diurnal variation. The total numbers of organisms are, however, shown above in italics where the hauls were made in daytime between the hours of 0600 and 1700, and the figures for species with a marked diurnal variation in lower latitudes are given in italics where the sample was taken in daytime. Where these species are absent from such samples a query indicates that they might conceivably have been present. Queries are also inserted where a sample is swamped by a large catch of *Euphausia superba*.

If the various stations in this table are compared it will be seen that at each of the seven most southerly stations (WS 544–51) the total number of organisms lies round about 6000–7000, while at the other stations the totals vary from 2000 to 24,000. *Euphausia frigida* occurs at all of the former stations at which it can be expected to be found, and at none of the latter. *Parathemisto* occurs at most of the northerly stations and at none from WS 544 onwards. *Euphausia superba* appears only in small numbers south of WS 555 and nowhere south of WS 547. *Haloptilus ocellatus* is taken only at WS 555 and at stations farther south, and *Pleuromamma* does not occur south of WS 555. The steadiness of the total numbers at WS 544–51 and the wide fluctuations at the more northerly stations is reflected in the composition of the plankton population. At the southerly stations each species is present in roughly similar numbers, while farther north no two adjacent catches are alike. At WS 536 for instance *Euphausia frigida* and certain copepods are all plentiful, while at WS 537 the same species, with the exception of *Metridia*, are either absent or much reduced. At WS 559 there was an enormous catch of *Calanus acutus* and *Metridia* was relatively abundant, while WS 539 differed from all the other stations in producing large numbers of *Thysanoessa*, all other species being scarce. Of all the samples from this line, from WS 561 to WS 555, the only two which seem to contain a similar plankton are WS 561 and WS 557, and these are widely separated from one another. In this line of stations, therefore, we can recognize two distinct faunistic areas, the more southerly one characterized by a very uniform plankton, and the more northerly one characterized, at least to the east of the South Sandwich Islands, by a sharply fluctuating plankton. Each of the two areas also seems to contain certain species which are absent from the other.

A distinction between these two areas is also found in the phytoplankton. Hart (1934) gives a chart (Fig. 47, p. 102) on which the total quantities of phytoplankton are shown for most of the stations included in Table IX. There were no phytoplankton samples for WS 544 and WS 546, but at the stations near the South Sandwich Islands the catches were variable and sometimes very large, while at the more southerly stations the catches were more uniform, and, on the average, considerably smaller. The change takes place, as with the macroplankton, between WS 543 and WS 545. There is also a qualitative change in the phytoplankton from the South Sandwich area to the southern stations, but this is not quite complete at WS 545.

No other samples are available from the eastern Weddell Sea, but Sts. 626–8 (Fig. 14) were taken about a month later on the east side of the South Sandwich Islands. At St. 627 the sample was swamped with krill, but Sts. 626 and 628 revealed two quite different types of plankton. Between South Georgia and the South Sandwich Islands we have first the William Scoresby's stations off the ice-edge in October 1928–9 (WS 287–310, Fig. 11). Among these the plankton did not show very much fluctuation, but they cover a small area and are not very illuminating. Sts. 360–2 (Fig. 12) are also close together, but the proportions of the various copepods vary sharply, though some of the other species are a little more uniform. The samples from Sts. 528 and 530 (Fig. 14) are quite similar except that about eight times as many *Calanus acutus* were taken at the former as at the latter. It seems then that on the occasions on which these regions have been visited the most variable plankton existed to the east of the Sandwich group, while there was a slightly less variable plankton between the Sandwich group and South Georgia.

The line of stations taken in October 1930–1 from Bouvet Island to South Georgia (Sts. 459–72, Fig. 14 and inset B) does not appear to cross any faunistic boundary. It is curious that although these stations are mostly in the "old" Weddell Sea water, which has presumably drifted up from the region of fluctuating plankton, the samples at each of them show a remarkable similarity. There are differences, described on p. 127, in the occurrence of certain cold-water species, but the distribution of the numerically important species along this line is very uniform. Thus *Calanus propinquus* was the dominant copepod at every station, *Euphausia frigida* was well represented throughout, *Limacina balea* was numerous at most stations, the occurrence of *Thysanoessa* was uniform and other species occurred mostly in small numbers. Only *Euphausia superba* had an irregular distribution.

The eastern part of the Scotia Sea, that is, the triangle formed by the South Sandwich Islands, South Georgia and the South Orkneys, also contains water from the Weddell Sea. Three lines of stations have been worked across this region: Sts. 372–5 in March 1929–30 (Fig. 12), 530–3 in December 1930–1 (Fig. 14), and 618–25 in February 1930–1 (Fig. 14). The latter two lines followed the edge of the pack-ice. The numbers of the numerically important species at these three lines of stations are shown in Table X, which is arranged on the same plan as Table IX on p. 138.

Table X. *Eastern Scotia Sea*

Date	March 1930				December 1930				February 1931							
	Open sea				Ice-edge				Ice-edge							
	West			East	West			East	West							East
Station	375	374	373	372	533	532	531	530	618	619	620	621	622	623	624	625
Hour	12	17	19	21	21	21	21	21	22	10	21	10	21	10	22	10
Calanus acutus	10	100	20	350	810	990	990	720	?	29	22	1600	64	22	400	640
Rhincalanus gigas	?	—	10	200	260	120	1200	3000	?	*19*	140	?	12	*10*	30	?
Euphausia superba	60	6400	570	850	—	1	12	8	5400	136	920	2	980	3	140	2
Thysanoessa sp.	*1100*	*850*	690	480	12	92	99	41	?	*33*	100	*59*	110	*22*	150	*33*
Calanus propinquus	*110*	8100	860	6400	100	248	96	240	?	*19*	140	?	12	*10*	30	?
Chaetognatha	*170*	10	—	30	110	23	220	940	?	?	—	*420*	—	?	15	*1*
Euphausia frigida	?	*50*	800	450	59	56	18	16	?	?	64	?	5	?	29	*1*
Metridia gerlachei	?	?	?	—	6100	220	180	280	?	?	3	?	—	?	—	?
Calanus simillimus	*290*	*50*	210	—	—	—	—	—	?	?	—	?	—	?	—	?
Pareuchaeta sp.	?	?	*10*	400	80	—	—	40	?	*1*	2	*8*	56	?	110	?
Total organisms (excluding shoaling species)	*1700*	9200	2600	8500	7700	1800	2900	5400	?	*100*	920	*2500*	690	*138*	1500	*970*

The principal conclusion to be drawn from this table is that, while quite a different type of plankton was taken on each of the three lines, the plankton at the individual stations of each line was of the same type. In other words, the samples suggest that in the eastern Scotia Sea the plankton is comparatively uniformly distributed, though its constitution may differ at different times. Some species in these lines are more evenly distributed than others. In the first line *Calanus acutus* is present at each station in numbers which are very small for this species, and *Thysanoessa* increases steadily to the westward. *Calanus simillimus* appears to do the same, while *Pareuchaeta* and *Euphausia frigida* seem to become reduced, though allowance must be made for their diurnal variations. The numbers of *Calanus propinquus* are more variable. The plankton revealed by this line is thus not so uniform as it was in the eastern Weddell Sea (WS 544–51), but it is more so than in the area to the east of the Sandwich group. In the second line (WS 530–3) the numbers of *Calanus acutus* are very steady, *Rhincalanus* and the Chaetognatha decrease to the westward, *Euphausia superba*, *Thysanoessa* and *Euphausia frigida* are uniformly scarce, and the numbers of *Calanus propinquus* and *Metridia* show no important fluctuations except for the large number of the latter taken at St. 533. This, however, was something of the nature of a shoal. Thus the plankton taken on this line was very uniform, and comparable to that of the eastern Weddell Sea. On the third line also we have quite a uniform plankton. Allowance must be made for the alternate day and night stations, and it will be seen that, apart from the exceptional catch of *Calanus acutus* at St. 621, no important fluctuations occur in the numbers of each species.

THE BELLINGSHAUSEN SEA

In the Bellingshausen Sea two lines of stations have been worked westward from Adelaide Island to a point beyond Peter 1st Island. These were the 'Discovery II' stations in 1930–1 (Sts. 561–82, Fig. 14) and the 'William Scoresby' stations in 1929–30 (WS 502–8, Fig. 13). On both cruises the stations were taken at or near the ice-edge. There have also been two shorter lines of stations running north-westwards from Adelaide Island—that of the 'Discovery II' in 1930–1 (Sts. 583–97, Fig. 14) and that of the 'William Scoresby' in 1929–30 (WS 509–17, Fig. 13). Other stations in the Bellingshausen Sea lie up and down the coast of Adelaide Island, the Biscoe Islands and the Palmer Archipelago.

During the cruise of the 'Discovery II' to the western Bellingshausen Sea twelve stations were taken on the outward journey (Sts. 561–72) and ten on the return (Sts. 573–82), and these are arranged in their relative positions on the line in Table XI, as in Table IX.

Reference has already been made (p. 110) to the thin plankton of the eastern Bellingshausen Sea (near Adelaide Island, etc.), and this is clearly shown in Table XI at stations east of St. 579. At the westerly stations the plankton tends to be rich, but there is great variation in the size of the samples. However, the composition of the plankton is very similar at these stations in spite of the fluctuations in abundance. *Rhincalanus* is usually the dominant copepod, though *Calanus acutus* is more numerous at one or two stations,

Table XI. *Bellingshausen Sea*

Date	January 1931										
Station	West 572	571	570	573	569	574	568	575	576	567	577
Hour	20	09	22	10	11	22	22	10	21	10	10
Calanus acutus	560	880	14,000	360	400	36	20	4,600	12	4700	480
Rhincalanus gigas	1700	*2100*	4,700	*4500*	*1100*	210	1900	*12,000*	290	*840*	*9,400*
Euphausia superba	—	—	—	—	—	1	—	76	2	—	—
Thysanoessa sp.	32	?	63	*17*	*17*	3	1	*110*	73	*110*	*4*
Calanus propinquus	60	?	160	*80*	*8*	14	—	*80*	68	?	?
Chaetognatha	290	*140*	210	*480*	*180*	10	100	*470*	8	*230*	*160*
Euphausia frigida	—	*6*	—	*11*	?	—	16	?	—	?	?
Metridia gerlachei	300	*60*	160	?	*40*	—	—	?	—	?	?
Salpa fusiformis f. *aspera*	1	*39*	—	*9*	*57*	56	370	?	—	*550*	*290*
Limacina helicina	23	4	73	12	22	120	280	9	36	82	110
Total organisms (excluding shoaling species)	3100	*3200*	19,000	*5400*	*1800*	410	2300	*18,000*	490	*6100*	*10,000*

Date	January 1931										
Station	566	565	578	564	563	579	580	562	581	582	East 561
Hour	22	10	22	22	11	10	22	22	20	10	10
Calanus acutus	160	760	900	350	780	1100	99	76	360	55	5
Rhincalanus gigas	7200	*5600*	540	160	*1200*	*470*	16	1	130	*35*	*1*
Euphausia superba	—	—	4	—	—	24	3	2	1	2	3
Thysanoessa sp.	22	6	15	120	*34*	*38*	250	4	96	*2*	*52*
Calanus propinquus	—	?	48	96	*920*	*16*	12	12	18	*7*	*26*
Chaetognatha	170	*410*	100	6	*7*	?	—	—	—	?	?
Euphausia frigida	16	?	—	—	?	?	—	—	—	?	?
Metridia gerlachei	—	?	104	—	?	*16*	2	—	34	*2*	?
Salpa fusiformis f. *aspera*	66	*4*	—	—	?	?	—	—	—	?	?
Limacina helicina	630	40	14	28	33	10	4	2	—	6	1
Total organisms (excluding shoaling species)	8300	*6900*	1700	780	*3000*	*1600*	390	100	650	*110*	*85*

and it is in fact the variations in the numbers of these two species which are responsible for the variations in the total numbers of organisms. The other species, which are not very abundant, occur in quite uniform numbers.

Table XII shows the results of the 'William Scoresby' line of stations.

WS 508 is in the region of thin plankton in the eastern Bellingshausen Sea, but heavy catches were taken at the other four and the plankton becomes progressively richer towards the west. Apart from this increasing abundance the plankton is very similar at each of these stations. It resembles that of the 'Discovery II' line in the scarcity of Euphausians and in the numbers of *Rhincalanus* and *Limacina*, but differs from it in the great abundance of *Calanus acutus*, and in the larger numbers of *Calanus propinquus* and Chaetognatha.

These two lines of stations indicate that the Bellingshausen Sea may be divided, in respect of its plankton population, into two regions: the eastern part which contains a thin plankton, and the western part which normally has a rich plankton. The quantity of plankton in the western part seems liable to vary very much from place to place, but its composition seems to be quite uniform.

Table XII. *Bellingshausen Sea*

Date	January–February 1930				
	West				East
Station	WS 503	WS 502	WS 504	WS 505	WS 508
Hour	19	13	18	14	02
Calanus acutus	31,000	21,000	13,000	13,000	640
Rhincalanus gigas	5,900	*2,200*	2,000	?	—
Euphausia superba	—	—	—	10	1
Thysanoessa sp.	17	*100*	9	*1*	20
Calanus propinquus	1,000	*510*	64	*450*	170
Chaetognatha	2,600	*1,500*	709	*120*	5
Euphausia frigida	—	?	—	?	—
Metridia gerlachei	*1,300*	*260*	*64*	?	48
Salpa fusiformis f. *aspera*	?	?	?	?	10
Limacina helicina	31	94	81	—	17
Total organisms (excluding shoaling species)	43,000	*26,000*	16,000	*13,500*	910

Various other stations have been worked in the eastern part of the Bellingshausen Sea, the most important of which are those taken by the 'Discovery II' in a line running north-westwards from Adelaide Island (Sts. 583–97, including stations on return journey). The numbers of the principal species taken are shown in Table XIII.

Table XIII. *Off Adelaide Island*

Date	January 1931														
	North-west														South-east
Station	592	591	593	590	594	589	595	588	597	587	596	586	585	583	584
Hour	02	20	10	10	16	01	00	19	12	14	05	09	05	22	01
Calanus acutus	28	8	1	6	12	3	11	4	6	15	5	3	78	66	29
Rhincalanus gigas	280	420	*100*	*1*	200	8	200	7	?	*4*	5	*2*	27	55	17
Euphausia superba	—	1	—	8	—	—	—	—	1	—	6	—	1	2	1
Thysanoessa sp.	2	2	*100*	*2*	6	20	5	2	*22*	*1*	1	*100*	28	38	12
Calanus propinquus	12	2	?	*1*	?	5	13	5	?	*3*	1	*4*	25	55	9
Chaetognatha	37	13	*4*	?	*20*	2	7	1	?	?	—	?	—	5	1
Euphausia frigida	10	—	?	?	?	1	1	—	?	?	—	?	—	—	—
Parathemisto gaudichaudi	7	8	15	—	3	—	4	1	—	—	1	—	—	—	—
Metridia gerlachei	8	—	?	?	?	—	2	?	?	?	?	?	*14*	—	7
Limacina helicina	95	40	44	22	49	4	10	—	—	7	8	3	13	2	24
Total organisms (excluding shoaling species)	570	500	*270*	37	*330*	51	280	21	*30*	*30*	22	*120*	200	220	110

It should be mentioned that the stations at the south-eastern end of the line (near Adelaide Island) were a little closer together than those to the north-west (see Fig. 14, inset A).

The table shows the same thin plankton that was found at stations east of St. 579 in Table XI. The poorest plankton of all is found in the middle, there is slightly more at the inshore end (south-east) and the largest catches at the north-west end where indeed one might expect to reach a region of richer plankton. The composition of the catches must be regarded as quite uniform. Only *Rhincalanus* varies to some extent, but where there are never more than a few hundred specimens in the samples, such fluctuations cannot be of much significance.

During her cruise in the Bellingshausen Sea the 'William Scoresby' also worked a line of stations north-westwards from Adelaide Island (WS 509–17, February 1929–30, Fig. 13, inset). This was a short line, however, and the stations were close together, so that it is of less importance here than the 'Discovery II' line. It may be mentioned that the catches were quite similar in size and composition to those in the Discovery samples, and the plankton seemed quite uniform along the line except at WS 515, where a surprisingly large catch was taken in which *Calanus acutus*, *C. propinquus*, *Metridia*, *Parathemisto* and *Thysanoessa* numbered three or four hundred each.

Other hauls taken in the Bellingshausen Sea include only some stations taken along the coastal region between Adelaide Island and the South Shetlands. There were six taken by the 'William Scoresby' at the beginning of January 1929–30 (WS 496–501, Fig. 13), five taken by the 'Discovery II' at the end of December 1930–1 (Sts. 556–60, Fig. 14), and five more by the same ship late in January of the same season (Sts. 598–603, Fig. 14). The samples taken at the ten stations of the 'Discovery II' were all very small, averaging about 130 organisms per haul. By far the largest of these was the catch taken at St. 598 which contained over 600 organisms of which *Metridia* formed the majority. At three of the 'William Scoresby' stations, however (WS 496, 497 and 501), quite large catches were taken, each containing several thousand specimens of *Calanus acutus*. None of the other species was very plentiful, but such catches are very unusual in these coastal regions.

It seems then that the eastern or coastal region of the Bellingshausen Sea is characterized by a thin plankton of fairly uniform distribution, but that here and there one or more species may become concentrated, as a result, perhaps, of some local peculiarity in the hydrological conditions.

THE ORKNEY-SHETLAND REGION

In this section those stations will be briefly considered which lie in the vicinity of the South Shetlands and South Orkneys and in the Bransfield Strait, a region characterized, as already noted, by a general scarcity of plankton.

In the Bransfield Strait three intensive surveys have been carried out, with lines of stations at short intervals, and between the South Shetland Islands and the South

Orkney Islands various stations have been taken, many of which were at the edge of the Weddell Sea pack-ice.

The three surveys of the Bransfield Strait were taken in February 1928–9, November 1929–30, and December 1930–1 (Figs. 15–17). It will not be necessary here to tabulate the numbers of each species taken at the different stations. If the catches of *Euphausia superba* are disregarded it may be said that every sample which has been taken from the Bransfield Strait has been an extremely small one, and if one sample (WS 393), which contained the exceptional quantity of 520 *Metridia*, is also disregarded, the largest catch from the three surveys contained only 300 organisms. It is known that the south side of the Bransfield Strait is occupied by Weddell Sea water, and the north side by water from the Bellingshausen Sea. The distribution of the macroplankton, however, does not appear to differ very much in different parts of the Strait, and with such small samples, many of them containing only twenty or thirty organisms, it is very difficult to establish a reliable correlation between the local hydrological conditions and the distribution of the macroplankton.

Between the South Shetland Islands and the South Orkney Islands there are no straight lines of stations, and usually only two or three stations have been taken at a time in this region, but in the 1930–1 season the 'Discovery II' worked eight consecutive stations in December along the ice-edge from near the South Orkneys towards the Bransfield Strait (Sts. 534–41, Fig. 14), and eight more in roughly the same position in March (Sts. 637–44, Fig. 14). The numbers of the principal species at these stations are shown in Table XIV.

Table XIV. *Shetland–Orkney region*

Date	December 1930–1								March 1930–1							
	West							East	West							East
Station	541	540	539	538	537	536	535	534	644	643	642	641	640	639	638	637
Hour...	23	20	17	12	06	21	10	21	06	23	18	14	09	23	05	21
Calanus acutus	76	60	37	60	?	1800	6	59	15	?	—	—	1	32	1	—
Rhincalanus gigas	2	15	25	*12*	?	40	*35*	47	1	?	—	?	?	16	1	—
Euphausia superba	10	4	68	27	7600	7	4	5	20	1800	7	590	23	810	15	1
Thysanoessa sp.	23	6	*26*	*508*	*144*	8	*83*	28	*16*	49	3	*26*	*3*	83	*19*	75
Calanus propinquus	—	4	3	?	?	30	*1*	24	1	*42*	2	?	*4*	380	*2*	72
Chaetognatha	6	360	14	*14*	?	100	*7*	5	—	?	—	?	?	—	?	—
Euphausia frigida	—	—	?	?	?	—	?	57	*1*	*220*	—	?	?	1	*7*	41
Parathemisto gaudichaudi	—	—	1	—	?	2	—	—	9	56	—	—	—	3	1	22
Metridia gerlachei	4	—	?	?	?	190	?	7	*22*	*1100*	?	?	*10*	2800	*8*	380
Salpa fusiformis f. *aspera*	—	—	?	?	?	79	?	89	?	*260*	?	*70*	*19*	55	*1*	300
Total organisms (excluding shoaling species)	120	450	110	*590*	?	2200	*130*	280	*65*	*1500*	5	*26*	*19*	3400	42	590

It will be seen from Fig. 14 that in both these lines the more westerly stations are closer together than the others.

This is still a definitely thin plankton, but it is richer than in the Bransfield Strait and much more variable. There are considerable fluctuations both in the total number of organisms and among the individual species. Apart from *Euphausia superba* the most variable species are *Metridia gerlachei*, *Calanus acutus* and *Salpa fusiformis*.

The other stations in this area are WS 202 (Fig. 10) which was remarkable for a heavy catch of *Metridia* (over 3000) and an exceptional number of *Parathemisto* (350), WS 380 and 381 (Fig. 11) at which the plankton was scarce except for a rather large number of Salps, and Sts. 613–15 (Fig. 14) at which Salps were again quite plentiful and other species scarce.

It appears, therefore, that the area between the South Orkneys and the South Shetlands is characterized, like the eastern part of the Bellingshausen Sea, by a plankton which is generally scarce, but which may be found here and there in comparatively large quantities, usually due to the concentration of one particular species.

THE NORTHERN ZONE

The lines of stations so far considered are those in waters which are covered by the pack-ice during a large part of the year. Those next to be considered are mostly in waters which are never reached by the ice. Numerous stations have been taken in this area and we may consider first the lines crossing Drake Passage. There are three of these lines (Figs. 11, 12, 14) and they are shown in Table XV, which gives for each station the numbers of the ten most abundant species in this region.

Table XV. *Drake Passage*

Date	February 1928–9					April 1929–30					March 1930–1				
	South				North	South				North	South				North
Station	WS 400	WS 401	WS 402	WS 403	WS 404	378	382	383	384	385	644	646	647	648	649
Hour...	10	00	13	01	13	12	01	10	20	08	06	17	00	13	23
Calanus acutus	—	17	20	32	64	13	800	800	—	—	15	—	810	64	40
Rhincalanus gigas	?	8	170	3500	5100	79	5200	1000	530	1500	1	11	1500	1500	330
Limacina balea	?	—	?	—	10	?	—	?	—	40	—	—	—	?	430
Thysanoessa sp.	33	—	180	3700	2200	16	50	220	150	18	16	64	500	8	290
Calanus propinquus	?	9	?	320	64	8	1900	100	440	?	1	—	160	16	88
Chaetognatha	?	—	16	380	880	?	660	320	370	6300	—	—	11	850	1600
Euphausia frigida	?	92	?	320	?	?	33	?	230	1	1	?	30	?	—
Parathemisto gaudichaudi	8	9	73	35	89	81	92	38	270	31	9	13	5	4	7
Calanus simillimus	?	—	2	160	?	?	—	20	—	20	1	1	160	16	88
Pareuchaeta sp.	?	84	?	350	32	?	400	10	310	?	?	?	40	8	130
Total organisms (excluding shoaling species)	43	290	460	9100	8400	200	9200	2500	2400	7900	65	89	3200	2500	2800

The most northerly station in each of these three lines lies close to the Antarctic convergence.

The first three stations of the 1928–9 line, the first station of the 1929–30 line and the first two stations of the 1930–1 line are in the region of thin plankton, and will be regarded as belonging to the Orkney–Shetland region. The others are in the normal plankton of the northern zone.

An inspection of Table XV will show that at WS 403 and WS 404, at Sts. 382–5, and at Sts. 647–9 there is a very uniform plankton. At all these stations *Rhincalanus* is the dominant copepod, *Limacina* is found only near the convergence, the Chaetognatha for the most part increase steadily towards the north, and *Pareuchaeta* and *Euphausia frigida* (except at St. 649) are present in moderate numbers at night stations. *Calanus acutus* and *C. propinquus* are a little variable, but *Parathemisto* has a uniform distribution in each line, except for a large catch at St. 384. *Thysanoessa* occurs in large numbers on the first line, but in smaller numbers on the other two. In general it may be said that there is a close similarity in the catches at consecutive stations across this part of the northern zone, and if one or two species, such as *Thysanoessa*, are excepted, it can be said that there was little difference between the plankton taken on the three lines.

North-east of Drake Passage there are several lines of stations lying roughly between the Falkland Islands and the South Shetlands and South Orkneys (Figs. 10, 12, 14). These stations and the principal species taken at them are shown in Table XVI.

Table XVI. *Between Falkland Islands and South Orkneys*

Date	April 1927–8		November 1929–30						March 1929–30			March 1930–1				
	South	North	South					North	South		North	South				North
Station	WS 203	WS 204	WS 474	WS 473	WS 472	WS 471	WS 470	WS 469	WS 527	WS 528	WS 529	637	636	635	634	633
Hour...	23	01	23	09	21	09	19	20	12	14	15	21	09	23	09	22
Calanus acutus	140	—	—	340	270	700	530	48	—	—	—	—	5	140	120	600
Rhincalanus gigas	940	52	1	*240*	340	*1300*	1300	660	*10*	?	?	—	*2*	580	*2200*	3,300
Limacina balea	48	5400	—	?	16	?	12	—	*10*	?	?	—	?	—	*180*	2,800
Thysanoessa sp.	190	—	160	*14*	33	*3*	1	230	*270*	*700*	*25*	75	*15*	710	*520*	4,700
Calanus propinquus	260	80	15	?	12	?	—	32	*790*	*18*	*60*	72	*3*	790	*80*	1,500
Chaetognatha	1200	1100	—	*160*	26	*400*	660	820	*670*	*60*	*10*	—	?	740	*2400*	1,400
Euphausia frigida	87	?	54	?	6	?	—	—	?	?	?	41	?	62	?	—
Parathemisto gaudichaudi	10	25	—	2	2	—	21	200	10	10	210	22	25	13	53	60
Calanus simillimus	16	160	—	?	4	?	16	—	*10*	?	?	—	?	200	?	680
Pareuchaeta sp.	96	92	—	?	—	?	?	—	?	?	?	—	?	120	*40*	880
Total organisms (excluding shoaling species)	3000	1600	240	*990*	750	*2500*	2600	2100	*1800*	*800*	*310*	590	*50*	3500	*5400*	15,000

The samples taken at WS 203 and WS 204 resemble one another only in respect of certain species. Thus the numbers of Chaetognatha, *Parathemisto*, and *Pareuchaeta* are similar, but *Rhincalanus* is the dominant copepod only at WS 203, and *Thysanoessa* occurs only at that station. The suggestion of an increase in the number of *Limacina* towards the north is in accordance with the conditions found in Drake Passage. The November line (WS 469–74) shows again the uniform plankton indicated in Drake Passage. At each station but one *Rhincalanus* is, as before, the dominant copepod, *Calanus acutus* is uniformly distributed in modest numbers and the Chaetognatha steadily increase towards the north. *Limacina*, *Thysanoessa*, *Calanus propinquus*, *C. simillimus*, and *Pareuchaeta* are scarce. WS 527–9 give curious results. The hauls were all taken in the middle of the daytime and consequently are not very reliable, but the plankton is not of the usual type found in the northern zone. The quantity is small, *Calanus* *propinquus* replaces *Rhincalanus* as the dominant copepod and the Chaetognatha diminish towards the north instead of increasing. The distribution of the plankton, however, seems to be quite uniform. In the 1930–1 line Sts. 637 and 636 are evidently in the area of thin plankton. At Sts. 635, 634 and 633, however, *Rhincalanus* is again dominant, *Calanus acutus* appears in moderate numbers, *Limacina* and the Chaetognatha increase towards the north and *Parathemisto* is evenly distributed in small numbers. The other species mostly increase towards the convergence, but the increase is in proportion to the increase in the total number of organisms, and the plankton here can be regarded actually as very uniform.

Table XVII. *Between Falkland Islands and South Georgia*

Date	February 1927–8			August 1928–9			December 1928–9			March 1928–9			
	NW		SE	NW		SE	NW		SE	NW			SE
Station	WS 140	WS 141	WS 142	WS 254	WS 255	WS 256	WS 316	WS 315	WS 314	WS 413	WS 414	WS 415	WS 416
Hour	21	17	10	13	03	01	16	19	13	13	05	17	16
Calanus acutus	260	1,500	3	—	—	16	110	130	68	—	290	670	2800
Rhincalanus gigas	400	7,500	*12*	?	1	160	2200	2300	*260*	*32*	2700	640	*1900*
Limacina balea	300	160,000	*300*	?	26	—	*120*	—	?	*280*	530	48	?
Thysanoessa sp.	180	2,700	*52*	*2*	130	560	6	260	*2*	*230*	150	*1600*	*6*
Calanus propinquus	3600	2,800	*2*	*2*	3	92	*16*	96	?	*460*	—	220	*64*
Chaetognatha	230	1,400	*38*	*1*	—	2	*220*	260	*160*	*1000*	440	*130*	*9*
Euphausia frigida	68	1,200	?	?	63	550	?	24	?	*8*	2	*830*	?
Parathemisto gaudichaudi	31	450	28	*2*	6	—	36	2700	72	26	42	50	260
Calanus simillimus	—	?	5	*2*	—	—	*80*	190	*52*	*300*	64	*260*	?
Pareuchaeta sp.	16	?	?	?	—	4	?	?	?	?	?	?	?
Total organisms (excluding shoaling species)	4900	18,000	*150*	*9*	210	1500	*2800*	6200	*640*	*2200*	3700	5500	*5000*

Date	April 1928–9				November 1929–30		February 1929–30						March 1930–1			
	NW			SE	NW	SE	NW					SE	NW			SE
Station	WS 430	WS 429	WS 428	WS 427	WS 466	WS 465	WS 521	WS 522	WS 523	WS 524	WS 525	WS 526	656	657	658	659
Hour	04	11	18	00	22	22	13	03	14	10	23	14	10	09	05	13
Calanus acutus	—	32	32	*32*	1500	224	—	96	—	—	2,600	32	—	—	6	—
Rhincalanus gigas	760	*3800*	670	*1100*	1000	2500	*830*	1900	*1200*	*800*	830	?	*138*	?	—	*2*
Limacina balea	1200	*120*	40	?	540	—	*22,000*	—	*72*	*72*	—	?	*150*	*3*	—	?
Thysanoessa sp.	250	*130*	140	*16*	48	800	*330*	3800	*840*	*150*	8,000	*150*	*12*	*16*	82	*34*
Calanus propinquus	120	*220*	350	*990*	—	—	?	320	*24*	?	3,000	*100*	?	*29*	52	*120*
Chaetognatha	730	*1100*	840	*2*	1800	1600	*790*	300	*78*	*56*	80	*4*	*100*	?	68	*22*
Euphausia frigida	—	?	350	*33*	—	32	?	1400	?	?	—	?	?	?	—	?
Parathemisto gaudichaudi	3	22	11	940	480	160	310	1	92	130	140	250	8	10	18	12
Calanus simillimus	56	*32*	450	*96*	5100	350	?	160	*64*	*16*	1,900	*32*	*2*	?	—	?
Pareuchaeta sp.	*48*	?	*16*	*420*	16	—	?	450	?	?	—	?	?	?	?	?
Total organisms (excluding shoaling species)	2100	*5400*	2900	*3800*	11,000	6300	*2,300*	8700	*2300*	*1200*	17,000	*630*	*260*	55	230	*190*

Finally, there are eight lines of stations lying between South Georgia and the Falkland Islands. These are shown in Table XVII and their positions in Figs. 10, 11, 12, 14.

Whereas other lines crossing the northern zone have at their southern or south-eastern ends an area of scarce plankton, most of these have at their south-eastern ends the rich plankton of the neighbourhood of South Georgia. The first line, however, (WS 140–2) is an exception, for in February 1927–8 the plankton was unusually thin around the north and west sides of South Georgia, and between WS 141 and WS 142 we find the familiar abrupt change from a rich to a poor plankton. It must be admitted that at these three stations the plankton is patchy. *Rhincalanus* is the dominant copepod at WS 141 and WS 142, but at WS 140 this species is far exceeded by the young stages of *Calanus propinquus*. At WS 141 the net evidently passed through a shoal of *Limacina*. Apart from these species, however, the differences between the three stations lie in the quantity rather than in the constitution of the plankton.

The next line (WS 254–6) was the only winter line across the northern zone, and is therefore hardly comparable with the others. The plankton of course was very thin, but had moderate numbers of Euphausians towards South Georgia. The plankton at WS 254, a midday station, was practically negligible.

At WS 314–16 there is again a rather sharp fall in the quantity of plankton from WS 315 to WS 314. At all three stations however *Rhincalanus* dominates the whole sample except for the exceptional catch of *Parathemisto* at WS 315. Other species are very uniform, though there is a slightly disproportionate number of *Thysanoessa* at WS 315.

At WS 413–16 the Chaetognatha increase steadily towards the convergence and *Calanus acutus* towards South Georgia. *Parathemisto* is fairly steady, but *Rhincalanus* is the most plentiful copepod only at WS 414. At WS 415 it is equalled, and at WS 416 it is exceeded by *Calanus acutus*. Euphausians are inclined to be irregular.

In the line WS 427–30 *Rhincalanus* is the principal copepod at all four stations. *Limacina* increases towards the convergence, and the Chaetognatha tend to do the same, though they fall off at WS 430. *Calanus propinquus* and *Thysanoessa* are quite evenly distributed, though the former increases a little towards South Georgia.

WS 465 is quite typical of the northern zone with its abundant *Rhincalanus* and Chaetognatha, but WS 466, which is almost on the convergence, has unexpectedly large numbers of *Calanus acutus* and *C. simillimus*.

In the line WS 521–6 there are more stations between the convergence and South Georgia than in any other. The quantity of plankton varies considerably, but this is largely due to the diurnal variations of *Thysanoessa*. At WS 522 and WS 525 the samples were taken near the middle of the night and at the other stations near the middle of the day, and at the former *Thysanoessa* was enormously abundant and at the latter relatively scarce. At WS 521–4 *Rhincalanus* was much the most abundant copepod, but at WS 525 and WS 526 (nearer to South Georgia) it was replaced by *Calanus acutus* and *C. propinquus*. *C. simillimus* was evenly distributed except at WS 525, and *Parathemisto* except at WS 522. There was the usual increase of Chaetognatha towards the convergence and a shoal of *Limacina* at WS 521.

The last line (Sts. 656–9) differs from nearly all other lines across the northern zone in the small amount of plankton taken at each station. *Parathemisto* and *Thysanoessa* are very uniform, and the Chaetognatha increase towards the convergence, but the commonest copepod at Sts. 657, 658 and 659 is *Calanus propinquus*, *Rhincalanus* being dominant only at St. 656. Apart from this, however, the plankton is similar in its make-up to the plankton found on other lines in this area.

Enough has been said now to show that the northern zone contains, during the summer, a plankton population sufficiently characteristic to form the basis of a separate faunistic area. The most important features of this plankton may be summed up as follows.

It is a population of homogeneously distributed typically warm-water species. *Rhincalanus* is generally the most abundant species and almost always has a large majority over other copepods. The Chaetognatha are nearly always present in large numbers near the convergence and in steadily decreasing numbers to the south or south-east of it. *Calanus simillimus*, *Pareuchaeta* sp. and *Euphausia frigida* are nearly always present in small or moderate numbers in the night hauls. Owing to their marked diurnal variations they are rarely taken in day hauls, but it is evident that they are usually quite evenly distributed over the whole area. The occurrence of *Calanus propinquus* and *Thysanoessa* is a little irregular, but if they occur in large numbers at one station in a line across the northern zone, it is probable that they will be taken also in large numbers at other stations in that line.

In general, it can be said that, in the northern zone, the summer plankton is both uniform and stable. That is to say that, compared with other parts of the area investigated, excepting perhaps the eastern Weddell Sea, a uniform type of plankton community is to be found everywhere at a given time, and that the plankton does not alter very much from month to month or from year to year. The northern zone seems to be a little more uniform and stable in the Drake Passage than it is between the Falkland Islands and South Georgia. In the latter region, however, there is known to be an eddy in the currents near the convergence, and this might be expected to cause some irregularities in the distribution of the plankton.

FAUNISTIC DIVISIONS

We are now in a position to map out the Weddell sector of the Antarctic in respect of the different types of plankton which have been found there, and it is possible, in my opinion, to distinguish seven separate divisions. These are shown in Fig. 48 and they may be defined as follows.

(1) *The northern zone*. This zone is bounded to the north by the Antarctic convergence, and to the south by the region of scarce plankton in the vicinity of the South Shetlands, and by the beginning of the transition zone in the vicinity of South Georgia. It is characterized by a uniform and stable plankton, in which *Rhincalanus gigas* is generally predominant; the Chaetognatha and *Limacina balea* are plentiful, especially near the convergence, and the typically warm-water species are fairly evenly distributed.

(2) *The Graham Land area*. This includes the whole of the region of scarce plankton

in the neighbourhood of the South Shetlands and South Orkneys, the Bransfield Strait and eastern part of the Bellingshausen Sea. The Shetland–Orkney region and the eastern Bellingshausen Sea can be regarded as subdivisions. It is characterized normally by a very thin plankton in which typically cold-water species are well represented. In some places there may be considerable irregularity in the quantity of plankton. The limits of this area are ill-defined near the South Orkneys, and uncertain on the west side of Drake Passage.

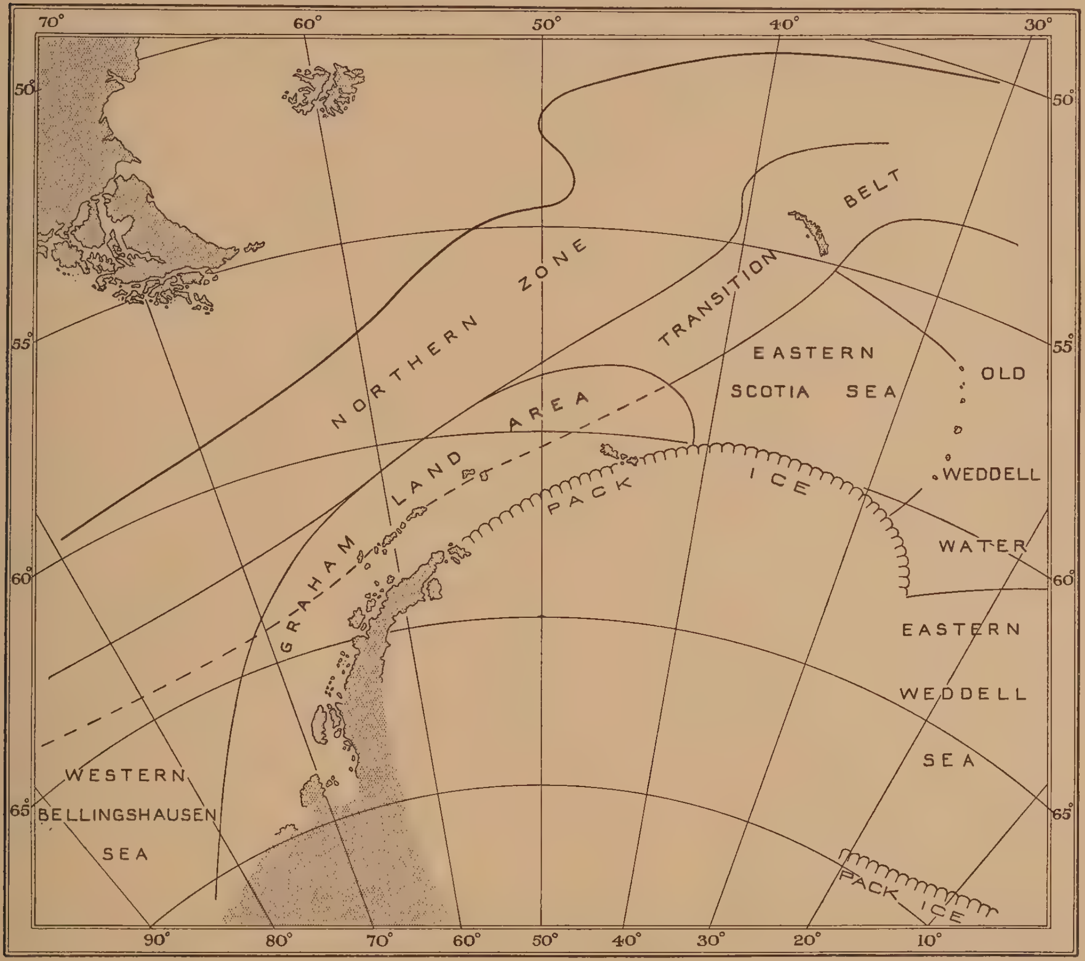

Fig. 48. Chart showing the provisional boundaries of areas in which distinctive plankton communities have been found.

(3) *The transition belt.* Derived from Fig. 21, p. 105. This is the belt in which the normal southern limits of the warmest water species and the northern limits of the coldest water species are found. One would expect to find the cold-water species prominent here in the early summer and the warm-water species later. This zone largely encloses the line separating the waters derived from the Bellingshausen and Weddell Seas, and may be taken to include South Georgia and the adjacent whaling grounds. Strictly

speaking it overlaps a part of the Graham Land area, which is defined on a different basis, for there is probably something of a transition zone everywhere to the south of the northern zone.

(4) *The eastern Scotia Sea.* A rough triangle, having at its corners the South Sandwich Islands, the South Orkney Islands and South Georgia. The area is characterized by a plankton which appears to be uniform but unstable. That is to say, a different type of plankton has been taken on the different lines of stations crossing this area, but the plankton was similar at consecutive stations in each line. The composition of the plankton seems to depend on the time of year, and very likely varies from one year to another.

(5) *The "old" Weddell water.* It is difficult at present to give any general definition of the plankton in this area, but it includes the unstable and heterogeneous plankton population found on the east side of the South Sandwich Islands. Its southern limit, at the time it was determined, lay between WS 544 and WS 555 (lat. 60° 40′ S, see p. 69), and north of this it may be temporarily defined as the area occupied by water which has flowed out of the Weddell Sea and passed the Scotia Arc in the vicinity of the South Sandwich Islands.

(6) *The eastern Weddell Sea.* The limits of this area are not known, but it lies south of WS 555, and, so far as can be judged from a single line of stations, the plankton is very uniform and characterized by a high proportion of the very cold-water species. It offers a marked contrast to the preceding division.

(7) *The western Bellingshausen Sea.* The exact limits of this area are also unknown, but it may be regarded temporarily as that part of the Bellingshausen Sea in which the plankton is rich in comparison with that found in the eastern part near Adelaide Island. The plankton taken here was in many ways comparable to that found in the eastern Weddell Sea, but it was rather more variable and the proportion of cold-water species was not quite so high.

It must be specially emphasized that these divisions are intended to do no more than represent the conditions as they were found at the time of investigation, and it would in fact be surprising if certain modifications of the scheme were not found to be necessary if the results of subsequent work are brought to bear on the question. It should also be mentioned that the boundaries between the different divisions are not geographically fixed lines. The Antarctic convergence may perhaps shift its position according to the time of year, and it has been seen (p. 121) that the change from the scarce plankton of the Graham Land area to the comparatively rich plankton of the northern zone has been found in quite different positions at different times. The distribution of the plankton should not, in any case, be thought of as a static pattern, but as a number of drifting communities whose formation must depend partly on their origin and the methods of propagation of the various organisms, and partly on the changing conditions through which they are carried. In the northern zone the current runs steadily from west to east with little interruption from islands, shoal waters, and varying ice conditions. This probably explains the regularity in the distribution of its plankton. The water flowing out of the Weddell Sea, on the other hand, impinges on the loop of the Scotia arc, and although the hydrological conditions in this region have not yet been worked out in detail, there can be little doubt that there are disturbances in the speed and direction of the currents. The most variable and fluctuating macroplankton was found, as we have seen, to the east of the South Sandwich Islands, and this is just where we should expect to find disturbances and eddies in the water, like the eddies formed in a river on the downstream side of a ford or the piers of a bridge. In the eastern Weddell Sea, where the drift of the water is undisturbed, we find again a uniform plankton population. Much of this area, as it is shown in Fig. 1, must contain water which is flowing westwards in the counter-current which is known to exist in the high latitudes, but the point at which the heterogeneous plankton of the old Weddell water changes to the homogeneous plankton of the eastern Weddell Sea (i.e. between WS 543 and WS 544), does not necessarily mark the division between the easterly and the westerly drift.

THE MACROPLANKTON AND THE DISTRIBUTION OF WHALES

It need hardly be pointed out that no immediate solution of the problem of the distribution of whales can be sought in a study of the general distribution of the macroplankton of the waters in which they live. A more direct connection no doubt exists between the movements of whales on the one hand and the distribution of "krill" and the hydrological conditions on the other hand. What we can hope for in a study of the associated plankton population is something in the nature of a symptom of the environmental conditions which are most favourable to the concentration of whales. The subject will not be pursued very far at the present stage, but it is worth while to mention one or two facts which suggest a link between the behaviour of whales and the distribution of the macroplankton in general.

The question is very difficult to approach because the movements and distribution of whales are influenced by more than one factor of major importance. It is known that they are migratory animals, visiting the warmer waters for purposes of breeding, and seeking their food in the cold waters of the Antarctic. We might assume then that the presence of a large concentration of whales in a particular place is to be explained on the grounds either that the whales have found there the environment which they require, or that they are on the way to, or looking for such an environment. The difficulty is to know which.

Around South Georgia and the South Shetland and South Orkney Islands whaling has been in progress for many years, and since the modern development of the factory ship the areas within which whales are caught has been vastly extended. The positions of the whaling grounds in the Atlantic sector of the Antarctic (as well as in other sectors) has been defined in recent papers by Hjort, Lie and Ruud (1932 and 1933). The charts published by these authors (1932, chart no. 1; 1933, pls. i, ii, v and vi), show that, though important changes take place during the season, most of the whaling in the

Atlantic sector is carried on at the ice-edge near the South Sandwich Islands, between Bouvet Island and the South Sandwich Islands and between the South Sandwich and South Orkney Islands. Ruud (1932, p. 76) also gives a useful chart showing the extent of the whaling grounds in the season 1929–30. If the charts of these authors are compared with Fig. 48, and it is remembered that South Georgia and the South Shetlands are also whaling areas, it will be seen that whales are sufficiently plentiful to be hunted in most of our faunistic areas, i.e. the Graham Land area (South Shetlands and South Orkneys), the transition zone (South Georgia), the eastern Scotia Sea (ice-edge whaling), and the "old" Weddell area (ice-edge whaling). During the cruises of the research ships continuous observations on whales have been made as far as weather conditions allowed, and our experience is that Blue and Fin whales may be met with anywhere in the Graham Land area, the transition zone, the eastern Scotia Sea, the "old" Weddell area, and the western Bellingshausen Sea. These are the same areas as those mentioned above in which whaling is conducted, but with the addition of the western Bellingshausen Sea in which whaling has not yet been developed. In the northern zone it has been observed that whales are very much scarcer, and in the eastern Weddell area practically none were seen. These are also the two areas (besides the Bellingshausen Sea) in which whales are not regularly hunted. In the period 1927–31 only one cruise was made in the eastern Weddell area, but during the recent second commission of the 'Discovery II' this area was revisited and I am informed that, as before, there was a notable scarcity of whales.

A comparison of Figs. 21 and 48 will show that the normal northern limit of the "krill" (*Euphausia superba*) corresponds with the southern boundary of the northern zone, and it has been seen that scarcely any "krill" was found in the eastern Weddell area (see Table IX, p. 138, WS 544–51). This no doubt accounts for the scarcity of whales in these two regions. It does occasionally happen, however, that a ship passing through the northern zone comes across a large herd of whales. Thus on November 12, 1929, when the 'William Scoresby' was in 58° 49′ S, 57° 50′ W, near the position of WS 471 (see Fig. 12, p. 80), many whales were seen in various directions from the ship, and were recorded as travelling in a southerly direction. There can be no question that these whales were on their way to the southern feeding grounds, and it would be safe to assume that any large body of whales met with in the northern zone is on its way to, or is returning from, the environment it requires in the Antarctic. Even in the areas which they commonly inhabit during the summer, the occurrence of the whales is, of course, very irregular. There are some places, however, in which they are more often found in large numbers than in other places. For instance in parts of the "old" Weddell area, especially to the east of the South Sandwich Islands, and in the eastern part of the Graham Land area around the South Orkneys and South Shetlands, enormous numbers of whales have been seen from time to time, while in the central part of the eastern Scotia Sea area large numbers of whales were rarely seen. The distribution of their food is no doubt the most important factor controlling the local distribution of whales, but there are other factors as well, for we must take into account the distinction between whales which are travelling and those which are not, and it is almost certain that the whales are influenced by the position of the pack-ice, the proximity of which is not necessary to the existence of "krill". Ruud (1932), in studying the connection between the whaling grounds and the distribution of *Euphausia superba*, points out that the "krill" is widely distributed in Antarctic waters, but suggests that the principal feeding grounds of the whales are in the "areas of convergence, backwaters, vortices of mixed layers, and in the centre of areas with a cyclonic motion", where a special concentration of "krill" is brought about. Since the present paper is concerned only with the distribution of the macroplankton as a whole, these conclusions cannot be examined in detail, but there are certain aspects of the distribution of the macroplankton which may have a bearing on them. We have seen that in the northern zone and the eastern Weddell area there are few whales and little or no "krill". These are also the two areas which apparently contain a particularly homogeneous plankton population, a fact which should presumably be attributed to the undisturbed flow of the ocean currents. In contrast to this an extremely variable plankton was found to the east of the South Sandwich Islands, and here the "krill" was abundant and Fin whales were very numerous. The complex plankton distribution suggests complex or disturbed hydrological conditions, which might be of the kind postulated by Ruud as favourable to the concentration of "krill". Around the South Orkney Islands also, and between the South Orkneys and the South Shetlands, the plankton, as we have seen, tends to be variable and patchy, and here again large numbers of whales are often seen. This apparent connection between a variable plankton and the occurrence of whales does not always hold good, however, for in the Bellingshausen Sea, between Sts. 565 and 566, and 577 and 578 (see Fig. 14) large numbers of whales were seen by the 'Discovery II', yet the plankton here could hardly be described as very variable and patchy (see Table XII).

There is reason also to believe that in certain circumstances some connection exists between the distribution of whales and the distribution of the total quantity of macroplankton. The evidence for this is inconclusive, but is worth mention. It has been shown by Kemp and Bennett (1932, p. 178) that during the first half of the whaling season at South Georgia, the whales are mostly to be found on the north-east side of the island, but that in the later part of the season there is a tendency towards a greater concentration on the south-west side. This tendency was noticeable in all four seasons of the period 1927–31. We have already seen that there is evidence to suggest a similar shift of the more abundant plankton from the north or north-east to the south or south-west side of South Georgia, and it seems possible that this shift of both whales and plankton may be due to some common cause. In particular the concentration of both whales and macroplankton on the south side of the island in February–March 1927–8, is very striking (compare Fig. 24 with Kemp and Bennett, pls. xi and xix). A further indication that concentrations of whales are connected with concentrations of macroplankton is to be found in the cruises to the Bellingshausen Sea by the 'William Scoresby' in 1929–30 and by the 'Discovery II' in 1930–1. The 'William Scoresby' took some plankton samples early in January in the eastern part of the Bellingshausen Sea (WS 496–501). Here the plankton was unexpectedly rich for these coastal regions, and large numbers of whales were seen in the vicinity. At the end of the month she travelled westwards from Adelaide Island to about 100° W, and taking stations on the return journey (WS 502–8), found a very rich plankton. During this cruise numerous whales were seen south of Peter 1st Island. From February 10–12 nine more stations were taken in the eastern Bellingshausen Sea off Adelaide Island (WS 509–17) and the plankton here was now found to be much poorer and no large numbers of whales were seen. During the next season (1930–1) the 'Discovery II' made a similar cruise, taking stations first in the eastern Bellingshausen Sea (i.e. off the Biscoe Islands and Adelaide Island) at the end of December (Sts. 556–60). Here the plankton was very thin and whales were sighted only occasionally. The ship then proceeded westwards to about the same point as that reached by the 'William Scoresby', and returned to Adelaide Island. During this part of the cruise (Sts. 561–82) a fairly rich plankton was found and, as with the 'William Scoresby' in the previous year, large numbers of whales were seen during part of the cruise, this time some distance to the north-east of Peter 1st Island. About the middle of January more stations were taken off Adelaide Island and the Biscoe Islands (Sts. 583–603) and again the plankton was scarce and very few whales were seen. The results are summarized in the following table in which the figures represent the average numbers of organisms per haul with the N 100 B. The numbers of stations upon which the averages are based are shown in brackets.

Table XVIII. *Whales and quantity of plankton in the Bellingshausen Sea*

	1929–30 ('William Scoresby')		1930–1 ('Discovery II')	
	Off Adelaide Island and Biscoe Island	Between Adelaide Island and 100° W	Off Adelaide Island and Biscoe Island	Between Adelaide Island and 100° W
Late December	— Many whales	—	102 (5 Sts.) Several whales	—
Early January	3300 (5 Sts.) Many whales	—	—	4263 (22 Sts.) Many whales
Late January	—	20,000 (5 Sts.) Many whales	113 (17 Sts.) Few whales	—
Early January	360 (8 Sts.) Several whales	—	—	—

The important point here is that the coastal region near Adelaide Island was visited four times. On three occasions the plankton was very scarce and whales were not plentiful. On the fourth occasion the plankton was about ten times as rich, and large numbers of whales were seen. This may be a coincidence, but it is suggestive, in view of the similar evidence from South Georgia, of a connection between the whales and the quantity of plankton. It is very improbable that the whales have any particular inclination to follow a rich macroplankton unless there is also a rich development of "krill", but it is quite possible that the hydrological conditions which give rise to a rich macroplankton are also in certain circumstances the conditions which provide the environment which the whales seek in the Antarctic.

It is obvious enough that the occurrence of whales does not vary regularly with the quantity of macroplankton. The Bransfield Strait, for instance, is normally exceedingly poor in plankton, and yet it is a region in which whales are known to be plentiful. We have already seen, however, that there must be more than one factor controlling the distribution of whales in the Antarctic, and consequently it cannot be expected that one set of circumstances will determine that distribution at all times and places.

SUMMARY

This paper is concerned with the plankton samples taken in Antarctic surface waters with the 1 m. oblique nets, and its object is to describe the horizontal distribution of the macroplankton as a whole. It is based on the analysis of about 600 samples collected in the period 1927–31.

The Antarctic convergence is the northern boundary of the area under consideration. Some Antarctic species are as common in the sub-Antarctic water on the north side of the convergence as they are in the Antarctic water on the south side, some occasionally stray into the sub-Antarctic water, and others are entirely confined to the south side of the convergence.

The amount of diurnal variation shown by each species has been estimated, and the average number per haul at different times of day and night plotted on graphs. It is found that there is every gradation between the species which can be caught in large numbers in the middle of the night but which are entirely absent in the middle of the day, and those which are taken equally at any time of day or night, or may even be commoner during the day. A period of daytime hours is allotted to each of the more variable species, and samples taken within that period are not regarded as valid indications of the presence or absence of the species in question.

Brief notes are given on the individual distribution of each species, and it is shown that some are typical of the colder water or high latitudes, some characterize the warmer water or lower latitudes, and others again may be taken equally in warm or cold regions.

The richness of the plankton varies greatly in different places and at different times. In the neighbourhood of the South Orkneys and South Shetlands, and in the eastern part of the Bellingshausen Sea the plankton appears always to be very scarce, possibly as a result of the upwelling of deep water. In other regions it is variable but generally very rich except during the winter months. It is possible that the boundary between the scarce plankton near the South Shetland Islands and the richer plankton of the Drake Passage may shift southwards in the latter part of the summer.

The distribution of species typical of warm or cold water is specially interesting. There is abundant evidence to show that in a given area the proportion of cold-water species in the plankton population becomes reduced as the summer goes on. There is

a high proportion of cold-water species in spring and a low proportion in autumn, and there is little doubt that the warm-water species remain dominant during the winter in spite of the lower temperature of the water. The distribution of the cold-water species appears to have some connection with the movements of the pack-ice, but in the lower latitudes, which are not reached by the pack, the same reduction takes place as the season advances. In a cold summer there is a higher proportion of cold-water species which, however, become reduced in the same way. The material, so far as it goes, suggests further that an exceptionally cold summer season in the Atlantic sector of the Antarctic may not necessarily be accompanied by a correspondingly cold season on the west side of the Drake Passage.

Different plankton communities can be distinguished in different water masses. Fig. 48 shows roughly the different areas in which a characteristic plankton population was found. These areas coincide to a large extent with different water masses. In the outer or northern zone of the Antarctic there is a uniform plankton population which undergoes little change in composition during the year. In other places, such as to the east of the South Sandwich Islands and in parts of the Orkney–Shetland region the plankton may fluctuate sharply from place to place and from time to time. It appears that where the hydrological conditions are uniform and undisturbed there is a uniform and stable plankton, and where the hydrological conditions are complex and variable there is a variable and unstable plankton population.

In the last section the connection between the macroplankton and the distribution of whales is discussed. It seems that whales are found in regions characterized by a variable plankton rather than in those with a uniform and stable plankton, and there is evidence which suggests that in certain circumstances the distribution of whales may be correlated with the distribution of the quantity of plankton.

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THE SUB-ANTARCTIC FORMS OF THE GREAT SKUA

(*CATHARACTA SKUA SKUA*)

By

J. E. HAMILTON, M.Sc.

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THE SUB-ANTARCTIC FORMS OF THE GREAT SKUA (*CATHARACTA SKUA SKUA*)

By J. E. Hamilton, M.SC.

(Plate I; text-fig. 1)

INTRODUCTION

The component forms of the genus *Catharacta* may be readily divided into four principal groups which are considered by Lowe and Kinnear (1930) to constitute a single species, *Catharacta skua* (Brünnich), of which the Great Skua is the type.

The four groups are:

(1) The Great Skua, *Catharacta skua skua* (Brünnich), which extends over the North Atlantic Islands to north-eastern America. Geographically it is completely isolated from all the other groups and there can be no doubt as to its individuality. There is usually, but not always, a strong chestnut cast in the plumage.

(2) The Chilian Skua, *Catharacta skua chilensis* (Bonaparte), occupying the east and west coasts of South America from Rio de Janeiro to Callao. This is the characteristic South American bird, but it extends to the Falkland Islands also. On the extreme eastern side of that group I have seen it mixing freely and breeding with the form which is numbered 4 below. The Chilian Skua is suffused with an even deeper chestnut colour than is the Great Skua.

(3) McCormick's Skua, *Catharacta skua maccormicki* (Saunders), is a strictly Antarctic form distinguished by the entire absence at all stages of chestnut colouring, by the vinous tinge of the lower surface, and usually by the presence of a conspicuous pale collar of acuminate feathers many of which are bright gold in colour.

(4) The sub-Antarctic Skua, *Catharacta skua* (subspecies), which may conveniently be termed the Brown Skua. This heading comprehends an assortment of birds which are found on all the sub-Antarctic islands, on the Tristan da Cunha group and on Gough Island. These birds may be described as brown in colour, often having on the neck yellow acuminate feathers which are, however, not so brilliant as the corresponding feathers of McCormick's Skua. Chestnut and pale markings are very frequently present, the former on the dorsal and the latter on both dorsal and ventral surfaces. The presence or absence of the chestnut patches on the feathers is quite fortuitous and sometimes they are not bilaterally symmetrical; a chestnut mark on one side may correspond to a pale mark on the other, so that it appears probable that the pale marks are due to the absence of chestnut pigment.

Wilson (1907, p. 67) believed that the condition of paleness was due to weathering of the plumage. In my opinion this is an error, due to the fact that the pale parts of the feathers are much more susceptible to the effects of weathering than are those parts which possess the darker pigments, brown and chestnut, as can easily be verified by examination of skins.

The number of specimens of the Brown Skua available for examination has been substantially increased since the publication of the *Birds of Australia* by G. M. Mathews in 1913, and the purpose of this paper is an examination of the validity of four subspecies named in that work. According to Lowe and Kinnear (1930) the following is the correct nomenclature:

Catharacta skua antarctica (Lesson), Falkland Islands, Tristan da Cunha and Gough Island;

C. s. clarkei (Mathews), South Shetlands, South Orkneys and South Georgia;

C. s. intercedens (Mathews), Kerguelen and Crozets; and

C. s. lönnbergi (Mathews) of the New Zealand region.

These subspecies are supposed to be distinguishable by differences in plumage and in the measurements of wing, tarsus and bill.

In order to facilitate an examination of the data I have adopted a division into seven geographical groups:

Locality	Number of specimens of which data are available
New Zealand area	29
Kerguelen and Crozets	10
Tristan da Cunha and Gough Island	8
South Georgia	9
South Orkneys	13
South Shetlands	12
Falkland Islands	40
	Total 121

PLUMAGE

As a preliminary it should be said that field observations must be accepted with reserve; it is extremely difficult and often impossible to say if a bird seen on the wing is large or small, pale or dark. Alterations in appearance due to background, movement or light are usually too numerous and sudden to permit of them being taken into account: it may be added that at a short distance at sea all brown skuas look dark, sometimes almost black.

The longest series of skins available for examination in the British Museum is that from the Falkland Islands; it contains thirty-seven specimens. Of these twenty-seven were collected by myself, but no attempt was made to pick out examples of any particular plumage phase—the birds were killed quite at random.

The thirty-seven specimens were all collected between November and April and none shows any sign of moult. Since the skuas leave the Falklands in April it follows that the moult must take place during the southern winter when the birds are absent from their breeding haunts, thus affording a contrast to the habit of McCormick's Skua which moults after the breeding season (Wilson, 1907, p. 74).

The birds from the Falkland Islands undoubtedly belong to one race, and even a superficial examination shows that it is very variable; dark, light and intermediate forms are all present. If the skins are arranged in order of size (as judged by wing length) it will be found that there is no correlation between colour and measurement.

As has been said on p. 164 the differences between the subspecies of Brown Skua are stated to be those of plumage and size, but in every subspecific group there is considerable individual variation, and so far as colour is concerned the specimens of any race may be matched by skins from the Falklands. There are, for example, two or three skins which have the dusky plumage supposed to distinguish Mathew's *lönnbergi* and, contrasting with them, are very light birds, plentifully splashed on the mantle with pale marks, which are identical with South Shetland specimens of *clarkei*. In view of so much agreement I do not consider that plumage differences can be regarded as valid subspecific (racial) characters.

MEASUREMENTS

The subject of differences based on dimensions may now be considered. The four standard measurements are those used by Lowe and Kinnear and are the following:

(1) *Length of wing* from the carpal joint to the tip of the longest primary, the manus having been straightened out as much as possible. This measurement must be considered as only approximately correct; complete accuracy is impossible since the amount of bending of the dried manus varies from one specimen to another and it is never possible completely to straighten it out.

(2) *Length of exposed culmen.*

(3) *Depth of bill at base of exposed culmen.*

(4) *Length of tarsus.*

Since it is obvious that the greater the variability of a character the less is its value in the separation of subspecies, I have attempted to determine the range of variation of the four measurements in each of my geographical groups. The measurements are shown in Table I and Fig. 1. Table II gives for each group firstly the average, minimum and maximum measurements, and secondly the divergence of the minimum and maximum from the mean, expressed as percentages of the latter, and range of variation also expressed as the percentage of the mean.

It will be observed that the lengths of the wing and tarsus are the least variable of the measurements, and that the depth of the bill shows greater range than the length.

Table I. *Measurements of* Catharacta skua

Locality and reference	Sex	Length of wing mm.	Length of bill mm.	Depth of bill mm.	Length of tarsus mm.
New Zealand					
Tring Museum	♂	442	56	24	77
B.M. 05.12.30.172	♂	424	53	22·5	76
B.M. 05.12.30.167	♂	423	51	23	95
B.M. 05.12.30.168	♂	421	55	24	78·5
B.M. 05.12.30.177	♀	447	55	26·5	79
Tring Museum	♀	437	57	24	80
,, ,,	♀	437	56	25	81
B.M. 05.12.30.178	♀	435	56	25	79·5
Tring Museum	♀	434	56	23	80
B.M. 97.12.6.41	♀	430	54	24	79
B.M. 43.7.11.38	♀	425	48	23	74
Tring Museum	♀	424	58	25	82
,, ,,	♀	418	57	23	78
,, ,,	♀	410	55	21	78
,, ,,	♀	407	57	23	77
B.M. 93.6.24.1	—	443	51·5	22	75
B.M. 01.1.7.55	—	433	51	24	80
B.M. 51.7.18.34	—	431	—	—	81
B.M. 91.6.16.44	—	431	—	23	84
B.M. 92.4.15.1	—	429	52·5	23·5	80
Tring Museum	—	421	59	24	78
,, ,,	—	420	55	25	79
B.M. 91.12.16.51	—	419	53	24	78
Tring Museum	—	415	56	23	76
,, ,,	—	411	57	22	78
,, ,,	—	407	57	23	82
B.M. 45.7.6.68	—	405	51	22	81*
B.M. 91.6.11.15	—	395	53	24	84
B.M. 03.3.20.3	—	—	56	23	83
Kerguelen and Crozets					
Tring Museum	♂	398	56	22	75
B.M. 09.11.16.9	♀	422	57·5	22	77·5
Tring Museum	♀	414	57	22	76
B.M. 41.768	—	410	52	23	78
B.M. 76.4.26.22	—	406	57	24	78
B.M. 09.11.16.8	—	403	49·5	20·5	71·5
B.M. 80.11.18.734	—	402	54	22·5	74
B.M. 41.767	—	401	53·5	22	74·5
B.M. 91.6.16.8	—	395	54	22	76
B.M. 80.11.18.734	—	395	50	20	73·5
South Georgia					
B.M. 14.3.8.48	♂	414	49	22·5	72
B.M. 14.3.8.49	♂	403	54	22	76
Tring Museum	♂	401	54	22	75
B.M. 22.12.6.32	♂	396	50	22	74
B.M. 14.3.8.50	♂	395	52	23	71
B.M. 22.12.6.36	♀	422	52·5	22·5	77
Tring Museum	♀	400	55	22	75
,, ,,	—	421	58	23	77
,, ,,	—	397	56	24	76

* From the Cape of Good Hope.

Table I (*cont.*)

Locality and reference	Sex	Length of wing mm.	Length of bill mm.	Depth of bill mm.	Length of tarsus mm.
South Orkneys					
Royal Scottish Museum	—	422	56	—	78
” ” ”	—	419	52	—	73
” ” ”	—	418	49	—	79
” ” ”	—	415	49	—	78
” ” ”	—	412	46	—	72
” ” ”	—	412	52	—	77
” ” ”	—	411	53	—	72
” ” ”	—	411	52	24	76
” ” ”	—	410	44	—	77
” ” ”	—	406	52	—	74
” ” ”	—	406	51	—	71
” ” ”	—	403	53	—	76
” ” ”	—	401	50	—	72
South Shetlands					
B.M. 24.5.8.85	♂	415	52	23	75
B.M. 23.9.10.1	♂	414	48	21	72
B.M. 24.5.8.86	♂	410	50·5	22	75
Paris Museum	♀	427	50·5	23	72
B.M. 24.5.8.8	♀	392	49	22	73
B.M. 24.5.8.83	—	400	50	22	72
Paris Museum	♂	406	53	23	68
B.M. 24.5.8.9	♂	375	47	18·5	65
B.M. 24.5.8.10	♀	393	44	19	64
B.M. 24.5.8.7	♀	381	46	19	68
B.M. 24.5.8.4	—	392	46·5	20	66
B.M. 23.9.10.2	—	387	50	19	63
Falkland Islands					
B.M. 15.xii.30	♂	390	46	19	67
B.M. 4.i.31	♂	390	46	20	64
B.M. 19.i.32	♂	385	48	20·5	67
B.M. 17.xii.30	♂	381	46	19·5	66
B.M. 9.i.31	♂	380	47	19·5	65
B.M. 18.xii.30	♂	379	45	20	67
B.M. 4.i.31	♂	374	45	19·5	63
Tring Museum	♂	372	51	20	69
B.M. 4.i.31	♂	371	45	19·5	63
Tring Museum	♂	370	49	21	68
B.M. 1.iii.32	♂	370	44	19	64
B.M. 17.xii.30	♂	360	47	18·5	64
B.M. 17.xii.30	♂	360	47	19·5	68
B.M. 13.i.30	♀	400	47	19	67·5
B.M. 26.i.31	♀	396	51·5	19	70
B.M. 4.i.31	♀	394	48	19·5	69
Tring Museum	♀	389	50	21	68
B.M. 9.i.31	♀	389	49	21·5	66·5
Tring Museum	♀	388	52	21	69
B.M. 9.i.31	♀	387	50	22·5	67
B.M. 28.i.32	♀	387	49	21·5	70
B.M. 4.i.31	♀	383	46	20·5	69

Table I (*cont.*)

Locality and reference	Sex	Length of wing mm.	Length of bill mm.	Depth of bill mm.	Length of tarsus mm.
FALKLAND ISLANDS (*contd.*)					
B.M. 26.xi.30	♀	383	45	21	67
B.M. 19.i.32	♀	381	46	20·5	64
B.M. 17.xii.30	♀	380	48	19·5	67·5
B.M. 18.xii.30	♀	380	47	19·5	69
B.M. 20.xi.31	♀	380	47	19·5	65
B.M. 91.5.22.61	♀	380	48	20	69
B.M. 26.xi.31	♀	379	46	21·5	64
B.M.	♀	377	47	20·5	69
Tring Museum	♀	377	50	21	69
B.M. 25.i.32	♀	374	47	19·5	65
B.M. 80.11.18.735	♀	368	47	20·5	69
B.M. 1894.10.28.3	—	394	49	20	67
Tring Museum	—	385	51	20	67
B.M. xi.30	—	385	46	21	72
B.M. xi.30	—	383	47	20·5	69
Royal Scottish Museum	—	382	46	—	70
B.M. 91.5.22.60	—	370	47	20·5	66·5
B.M. i.31	—	368	48	20·5	69
B.M. 1894.10.28.2	—	365	48	20	68
TRISTAN DA CUNHA GROUP AND GOUGH ISLAND					
Tring Museum	♂	385	53	21	70
B.M. 22.12.6.33	♂	385	50·5	20·5	73
B.M. 22.12.6.35	♂	381	52	22	73·5
Royal Scottish Museum	♂	373	51	—	69
B.M. 22.12.6.34	♀	396	53·5	24	75·5
Tring Museum	♀	390	55	22	72
,, ,,	♀	380	54	22	71
Royal Scottish Museum	—	389	54	—	75

The majority of the above measurements have been extracted from *British Antarctic* (*'Terra Nova'*) *Expedition*, 1910, Lowe and Kinnear (1930).

The specimens referred to "Tring Museum" are now in America.

It is of particular interest that the two longest series of specimens have the greatest variability in length of wing and tarsus, thus suggesting that a short series may well fail to exhibit the degree of variation to which a group is liable and is therefore the worse basis for subspecific differentiation—a point which has apparently been overlooked occasionally in the past.

Table II. Catharacta skua. *Mean, minimum and maximum measurements*

		New Zealand	Kerguelen and Crozets	South Georgia	South Orkneys	South Shetlands (all specimens)	South Shetlands (tarsus over 70 mm.)	South Shetlands (tarsus under 70 mm.)	Falkland Islands	Tristan da Cunha group and Gough Island
MEASUREMENTS		mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Length of wing:	Mean	424·1	404·6	405·4	411·2	399·3	409·7	389·0	380·0	384·9
	Minimum	395	395	395	401	375	392	375	360	373
	Maximum	447	422	422	422	427	427	406	400	396
Length of bill:	Mean	54·7	54·0	53·4	50·7	48·9	50·0	47·7	47·5	52·9
	Minimum	48	49·5	49	44	44	48	44	44	50·5
	Maximum	59	57·5	58	56	53	52	53	52	55
Depth of bill:	Mean	23·5	22·0	22·6	No data	21·0	22·2	19·7	20·2	21·9
	Minimum	21	20	22	No data	18·5	21	18·5	18·5	20·5
	Maximum	26·5	24	24	No data	23	23	23	22·5	24
Length of tarsus:	Mean	79·8	75·4	74·8	75·0	69·4	73·2	65·7	67·2	72·4
	Minimum	74	71·5	71	71	63	72	63	63	69
	Maximum	95	78	77	79	75	75	68	72	75·5
GREATEST DEPARTURES FROM MEAN, AND RANGE OF VARIATION		%	%	%	%	%	%	%	%	%
Length of wing:	Below mean	6·1	2·4	2·6	2·5	6·1	4·3	3·6	5·3	3·1
	Above mean	5·4	4·3	4·1	2·6	6·9	4·2	4·4	5·3	2·9
	Range of variation	11·5	6·7	6·7	5·1	13·0	8·5	8·0	10·6	6·0
Length of bill:	Below mean	12·2	8·3	8·2	13·2	10·0	4·0	7·8	7·4	4·5
	Above mean	7·9	6·5	8·6	10·5	8·4	4·0	11·1	9·5	4·0
	Range of variation	20·1	14·8	16·8	23·7	18·4	8·0	18·9	16·9	8·5
Depth of bill:	Below mean	10·6	9·1	2·7	—	11·9	5·4	6·1	8·4	6·4
	Above mean	12·8	9·1	6·2	—	9·5	3·6	16·7	11·4	9·6
	Range of variation	23·4	18·2	8·9	—	21·4	9·0	22·8	19·8	16·0
Length of tarsus:	Below mean	7·3	5·2	5·1	5·3	9·2	1·6	4·1	6·2	4·7
	Above mean	19·0	3·4	2·9	5·3	8·1	2·5	3·5	7·1	4·3
	Range of variation	26·3	8·6	8·0	10·6	17·3	4·1	7·6	13·3	9·0

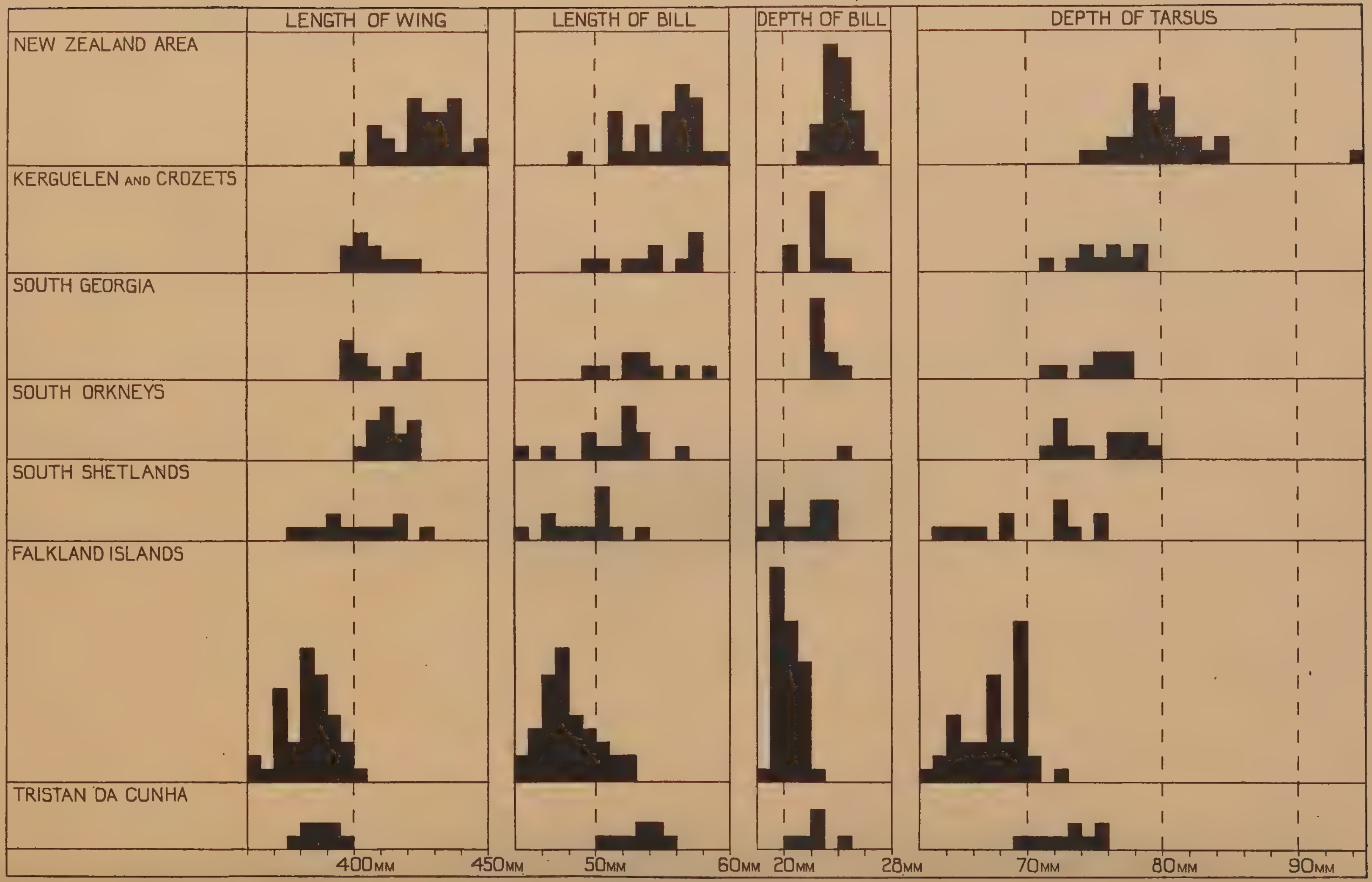

Fig. 1. Measurements of *Catharacta skua*.

GEOGRAPHICAL GROUPS

Tables I and II contain the numerical data for each of the seven groups, which are arranged in order from east to west.

New Zealand and Falkland Islands. The differences in average measurements are greatest between the New Zealand and the Falkland Islands groups, which are also the farthest apart, and if these, the extremes, are compared first the positions of the intermediate groups will be easier to define.

Measurements from forty-one Falkland birds are available, and of them thirty-four are in the British Museum, while the New Zealand specimens are twenty-nine in number with sixteen in the British Museum.

One New Zealand specimen has a tarsal length which is altogether exceptional, 95 mm., the next highest being 84 mm.; the isolation of the larger measurement suggests that it may be the result of development which is not quite normal. Between the two series the wing measurements do not overlap; but the difference is only 7 mm., less than 2 per cent of the maximum for the Falkland Islands (400 mm.), and this 7 mm. is quite possibly within the error of measurement (p. 165). There is a noticeable overlapping in bill measurements, and in tarsal length there is a difference of only 1 mm. (Fig. 1).

In spite of this close approximation the New Zealand birds are on the whole larger than those from the Falklands and they often have rather duller plumage and a less developed yellow collar. But, since there are no real plumage differences and no abrupt hiatus between the series of measurements, the two forms cannot be regarded as being more than subspecies of *Catharacta skua*, as is suggested by Lowe and Kinnear, and the names used by these authors should be retained, namely *C. s. antarctica* (Lesson) for the Falkland Islands form and *C. s. lönnbergi* (Mathews) for that of the New Zealand region.

Kerguelen and Crozets. The other groups of Brown Skua may now be considered in accordance with their distribution.

Nearest in space to *lönnbergi* is the race from the Crozets and Kerguelen: it has been distinguished as *C. s. intercedens* by Mathews. An examination of the eight specimens in the British Museum shows that there is no difference between them and the New Zealand birds so far as plumage is concerned.

It will further be observed that the measurements of eight out of the ten specimens from which the data were taken fall within the limits of the dimensions of *lönnbergi*, in spite of the fact that the average of the wing lengths is 20 mm. less than the corresponding figure for that race (Fig. 1). In the other measurements there is a difference of 1 mm. in the depth of the bill, of 1 mm. in the length of the tarsus of one specimen, and of 2·5 mm. in the length of the tarsus of another. It appears, then, that the distinction between these two races rests on the possession of a wing which may be, but is by no means always, shorter in the Kerguelen bird, and in the occasional occurrence of a slightly shorter tarsus. Since it is known that the range of measurements in the Brown Skuas is considerable it cannot be considered that such slight differences are grounds for separating the Kerguelen group as a subspecies.

Support is given to this statement by a specimen from a position as far west as the Cape of Good Hope, where it would be reasonable to expect a representative of the Kerguelen race if it really had a separate existence; but on grounds of measurement the African bird should be placed in *C. s. lönnbergi*.

Another specimen, from Travancore, in the possession of Mr H. Whistler, should also be included in the *lönnbergi* subspecies. *C. s. intercedens* should be abandoned and the birds from Kerguelen and the Crozets included in *C. s. lönnbergi*.

SOUTH GEORGIA. The statements with regard to the Kerguelen birds apply also to those from South Georgia; there are no plumage differences of importance and the measurements of the nine specimens of which data are available fall almost without exception within the range of the dimensions of *C. s. lönnbergi* (Fig. 1). It follows that the section of *C. s. clarkei* (Mathews), which has been stated to occupy South Georgia, should be included in *C. s. lönnbergi*.

SOUTH ORKNEYS. In the matter of plumage Eagle Clarke (1915) states that in a series from the South Orkneys there are two types which, however, do not differ in size. One is a dark form which has few and sometimes no pale marks on the mantle, while the other is lighter with many pale marks on the back and sometimes on the breast. The pale form had "the yellow streaks on the neck much more numerous and pronounced than in the darker birds; and they agreed with the form described by Saunders...as inhabiting the Falklands except that they are not smaller than the ordinary dark form" (of the South Orkneys). "One of these light birds was observed to be mating with one of the dark examples." This occurrence of two roughly distinguishable types—a light and a dark—is common among the Brown Skuas, but there is no real division between the two phases, which grade into one another (p. 165).

There are no specimens from the South Orkneys in the British Museum; the measurements of Lowe and Kinnear are taken from the series in the Royal Scottish Museum and these are summarized in Table II. The average wing measurement is rather greater than that for South Georgia, and so is the tarsal length, but the bill length is rather less. That is to say in wing and tarsal measurement the South Orkney birds are nearer to the New Zealand group than are those from South Georgia.

Within the limits of the South Orkney group of specimens the bill varies as much as 11 mm. and the tarsus 8 mm., whereas the greatest difference from the New Zealand specimens is 4 mm. for the bill and 3 mm. for the tarsus. I do not consider that the South Orkney birds can be separated as part of *C. s. clarkei* on the basis of small and inconstant differences in measurements. Like those from South Georgia, therefore, the South Orkney skuas must be included in *C. s. lönnbergi* because the differences in measurements are so small and no separation is possible on the basis of plumage differentiation.

SOUTH SHETLANDS. In the South Shetlands the position is one of some interest. Details of twelve specimens are available, ten being in the British Museum and two in Paris. In the paper by Lowe and Kinnear (1930, p. 118), it will be observed that the list of *C. s. clarkei* includes only ten from the South Shetlands—those in the British

Museum; but under *C. s. maccormicki* (p. 122) a male and a female are recorded as having been taken by Charcot's expedition at Deception Island on December 2, 1909. In the report of Charcot's second expedition the list of *maccormicki* contains no corresponding data, but two examples, one of each sex, of *Megalestris antarctica* are included as having been killed at Deception on the date quoted (Gain, 1915, pp. 109–10). Since it is obvious that these two birds were quite accidentally added to the list of *maccormicki* which was sent to Lowe and Kinnear from Paris, I include them in my list of Brown Skuas from the South Shetlands.

Since there are only twelve specimens caution must be observed, but on reference to the figures it will be noticed that there appears to be a natural tendency for the birds to fall into two groups of six each, one of which has a tarsal length of over 70 mm. while in the other it is under 70 mm. The two groups are separated in the Table (p. 167).

The interesting point is that the measurements of the larger group, that is, with the longer tarsus, incline towards those of *lönnbergi*, while those of the smaller birds are nearer to the dimensions of the Falkland Islands subspecies, *C. s. antarctica.*

Plumage distinctions between the two South Shetland groups are non-existent, they do not differ materially from any other series of skins: one of the smaller birds, it may be remarked, has a particularly bright collar such as is found in some Falkland specimens.

CONCLUSIONS

There is found in the Falklands a smaller form of Brown Skua which frequently has a fairly bright collar of yellow acuminate feathers on the neck; the wing seldom attains a length of 400 mm. and the tarsus is almost always less than 70 mm. long. In the New Zealand area there is a larger bird which often lacks the yellow collar and has a tendency towards a duskier plumage, the wing almost always exceeds 400 mm. and the tarsus does not usually fall below 74 mm., but the differences in measurements and still more in plumage are by no means sharply defined between the two groups.

The specimens from the Crozets, Kerguelen, South Georgia and the South Orkneys are slightly smaller than the New Zealand birds, but the majority of the measurements overlap markedly and on grounds of plumage differences they cannot be separated at all.

Birds from the South Shetlands appear to fall into two groups, each of which contains darker and lighter forms; in their measurements the smaller birds resemble the Falkland Islands form, while the larger belong rather to the same group as the New Zealand specimens.

The skuas of Tristan da Cunha and Gough Island, except for the slightly shorter wing, are comparable to those of South Georgia and should be included with them.

At the risk of redundancy I would emphasize these two points:

(1) Plumage differences alone show themselves to be unreliable in separating the four subspecies of Brown Skua recognized by Lowe and Kinnear.

(2) With the exception of the birds from the Falkland Islands, some from the South Shetlands and one or two odd specimens besides, the measurements of all Brown Skuas

fall within the limits of variation of the New Zealand race, although rather in the lower part of the range of size.

There is no advantage in dividing up the Brown Skuas into four subspecies of which two are so ill defined that they cannot be identified except by reference to the localities on the data labels; the validity of subspecies should depend on the possession of intrinsic characters. It follows therefore that groups which cannot be differentiated from the New Zealand race should be included with it in one subspecies.

It is my opinion that the Brown Skua should be divided into two subspecies, a larger and a smaller, which have a common meeting place in the South Shetlands. The names and distribution are: *C. s. antarctica* (Lesson), of the Falkland Islands and the South Shetlands, and *C. s. lönnbergi* (Mathews), of New Zealand, the Crozets, Kerguelen, South Georgia, the South Orkneys, Tristan da Cunha, Gough Island and the South Shetlands. *C. s. clarkei* (Mathews) and *C. s. intercedens* (Mathews) thus cease to exist, part of the former and the whole of the latter being absorbed in *C. s. lönnbergi* and the remainder of *clarkei* being included in *C. s. antarctica*.

NOTE ON THE DISTRIBUTION OF McCORMICK'S SKUA

L. Gain (1915) has stated that he found McCormick's Skua on Deception Island, South Shetlands, where it was mixing with the Brown Skuas but was more numerous. He found *maccormicki* nesting as far north as Admiralty Bay, 62° 6′ S, and mentions it as nesting at Port Lockroy in Wiencke Island, 64° 49½′ S. In the course of a number of visits to the South Shetlands by Mr A. G. Bennett and myself no specimen of *maccormicki* has been collected, and in my observation the whole area as far south as 65° of latitude is occupied by the darker bird, i.e. *C. s. antarctica*.

The brown form is abundant and nests at Deception, and while Gain records having seen it as far south as Wiencke Island at the south end of the Belgica Straits he states that it did not nest in the Straits. In 1922, however, I found that Port Lockroy had become a nesting site.

It may be suggested that the Brown Skua, which is slightly larger than *maccormicki*, favoured by the abundant food supply derived from the extensive whaling operations subsequent to 1909, had succeeded in ousting *maccormicki* from its former breeding places in the South Shetlands, at least as far south as Port Lockroy. It is well known that the skuas are most combative birds and even given to cannibalism at times.

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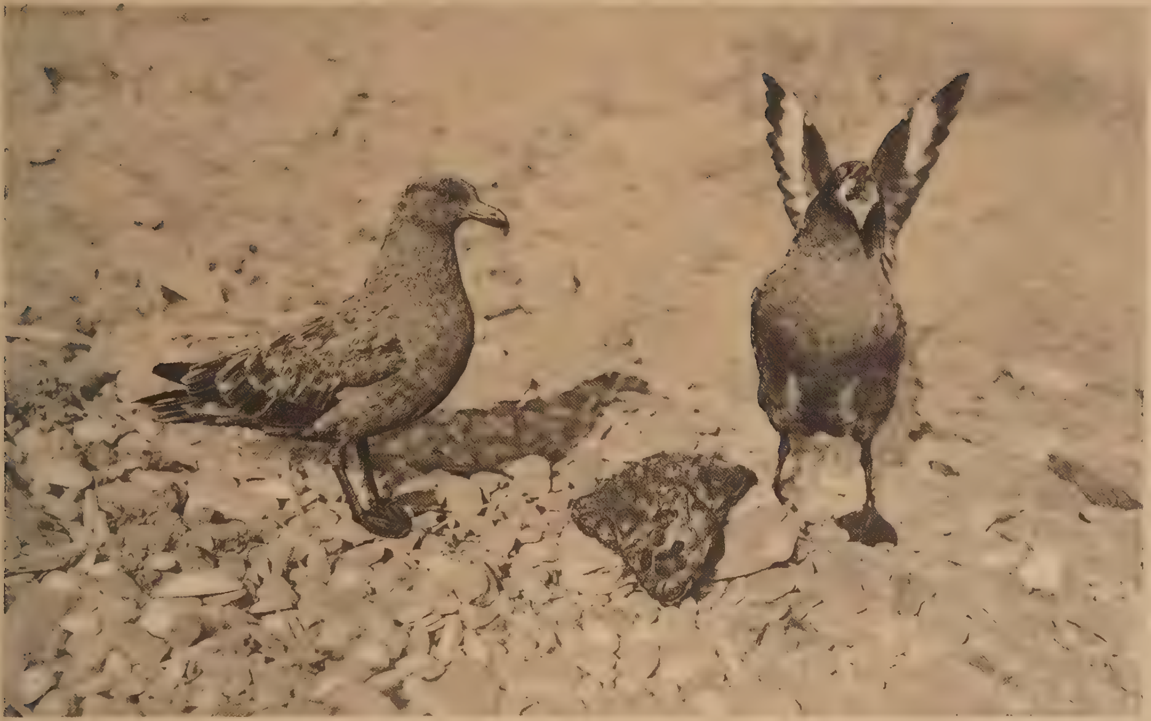
PLATE I

Fig. 1. *Catharacta skua lönnbergi* (Mathews). Adults, Cumberland Bay, South Georgia.

Fig. 2. *Catharacta skua lönnbergi* (Mathews). Chick about ten days old, South Georgia.

Fig. 3. *Catharacta skua*, either *lönnbergi* (Mathews) or *antarctica* (Lesson). Young chick, Port Lockroy, South Shetlands.



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CATHARACTA SKUA

[*Discovery Reports, Vol. IX, pp.* 175–206, *Plates II–XIV, August,* 1934.]

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THE MARINE DEPOSITS OF THE PATAGONIAN CONTINENTAL SHELF

By

L. HARRISON MATTHEWS, M.A.

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THE MARINE DEPOSITS OF THE PATAGONIAN CONTINENTAL SHELF

By L. Harrison Matthews, M.A.

(Plates II–XIV; text-figs. 1–3)

INTRODUCTION

This report is a description of the nature of the sea-bottom of the continental shelf lying off the coasts of Patagonia and Tierra del Fuego south of lat. 43° S. This region includes the Falkland Islands, and the Burdwood Bank which lies south of them. It has been the subject of fishery surveys made by the R.R.S. 'William Scoresby', when the region was explored by means of the large otter trawl, in addition to the usual oceanographic gear, to ascertain whether it could sustain a commercial trawl fishery. At many of the stations bottom samples were obtained with the conical dredge, and these form the subject of this report. From the biological standpoint the type and texture of the bottom deposits are of great importance when considered in relation to the animals and plants found living on or near the bottom, or burrowing into it. For this reason the deposits are here classified and charted into grounds showing the type and size of the particles that form them, providing data of the habitats of the organisms living on or near the bottom in the region examined.

TOPOGRAPHY OF THE SEA-BOTTOM OF THE REGION

The region from which bottom samples have been examined comprises the Patagonian continental shelf south of lat. 43° S, and part of the Burdwood Bank. The Patagonian continental shelf includes the Falkland Islands. Plate III shows the bathymetric configuration of the region. It is constructed from the soundings taken by the R.R.S. 'William Scoresby', with additions from the Admiralty charts of the region.

The limit of the continental shelf may be taken as the 200 m. contour. This contour roughly follows the sixtieth meridian from lat. 43° to 46° S, then bends westward to the neighbourhood of long. 61° W and follows this meridian to 49° S. Here it turns south-east to lat. 51° S and then skirts the outline of the Falkland Islands, following the east, south and west coasts to lat. 51° S in the neighbourhood of long. 62° W. At this point it turns south-west and runs towards the mouth of the Strait of Magellan as far as 64° 30′ W, where it again turns southerly and runs down to the eastward end of Staten Island.

South of the Falkland Islands, between lat. 54° and 55° S and long. 56° and 62° W, lies the Burdwood Bank, which shoals to less than 50 m. The bank is separated from the Falkland Islands and the Patagonian continental shelf by deep-water channels which run in from the south and west (sections *E*, *F*, *G*, Fig. 1), and join to form a bay cutting into the continental shelf between the Falkland Islands and the Patagonian coast.

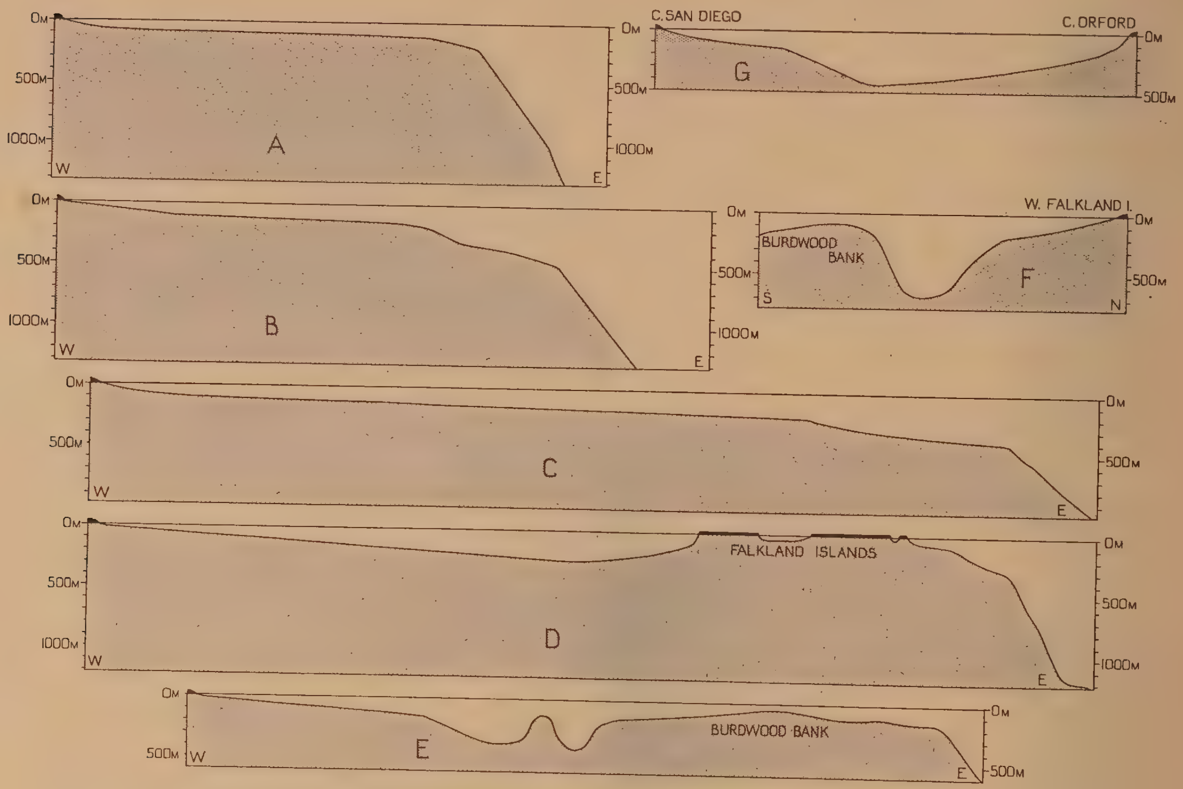

Fig. 1. Sections of the Patagonian continental shelf. *A*. Section in lat. 43° S. The continental shelf lies chiefly between 50 m. and 100 m. The bottom slopes less gently from 100 m. to 200 m. and then descends steeply. *B*. Section in lat. 47° 30′ S. The continental shelf lies chiefly between 100 m. and 200 m. The bottom slopes less gently from 200 m. and 500 m. and then descends steeply. *C*. Section in lat. 50° S. The continental shelf lies chiefly between 100 m. and 200 m. It slopes less gently to 400 m. and then descends steeply. *D*. Section in lat. 52° S. The section passes through the Falkland Islands and shows the proximity of the islands to the edge of the continental shelf. West of the Falkland Islands is seen the northern end of the bay of deeper water formed by the meeting of the channels separating the Burdwood Bank from the Falkland Islands and Tierra del Fuego. *E*. Section in lat. 54° 10′ S. The section passes through the Burdwood Bank and the coast of Tierra del Fuego. It shows a small bank lying in the deeper water channel separating the Burdwood Bank from the continental shelf. *F*. The section is taken on the sixty-fifth meridian between lats. 49° 55′ S and 54° 45′ S and shows the Burdwood Bank separated by deep water from the continental shelf south of the Falkland Islands. *G*. Section from Cape Orford, West Falkland Islands, to Cape San Diego, Tierra del Fuego. The section runs approximately NE to SW, passing NW of the west end of the Burdwood Bank, and crosses the bay of deep water that runs northwards from the channels separating the Burdwood Bank from the Falkland Islands and Tierra del Fuego.

The 100 m. contour lies at a distance of 60–100 miles from the coasts of Tierra del Fuego and Patagonia as far north as lat. 45° S. At this latitude it trends away from the coast in a north-easterly direction and approaches closely to the 200 m. contour east of long. 60° W. The northern part of the continental shelf is thus mostly under 100 m.

deep (section *A*, Fig. 1), while the southern part is mostly 100–200 m. deep (sections *B*, *C*, Fig. 1). The 100 m. contour round the Falkland Islands lies close to the coast so that the shores of the islands descend comparatively steeply to the level of the continental shelf, which on the east, south and west coasts of the islands is narrow.

Outside the limit of the continental shelf at 200 m. the bottom north of lat. 46° 20′ S runs steeply down to depths of 2000 m. and more (section *A*, Fig. 1). From lat. 46° 20′ to 50° S the 200 m. contour lies farther to the west and the seaward slope of the shelf is more gentle to 500 m., below which it dips steeply (sections *B*, *C*, Fig. 1). South of lat. 50° S the Falkland Islands lie close to the edge of the continental shelf and the steep slope from 300 m. downwards is near the coast (section *D*, Fig. 1).

The gradient of the continental shelf from the coast to the continental slope is very gentle: in lat. 43° S it is only 1 in 2690 for a distance of 160 miles from the coast out to the 100 m. line, and in lat. 50° S it is 1 in 3150 for a distance of 340 miles from the coast out to the 200 m. line.

DISTRIBUTION OF SAMPLING

The area of the region from which samples have been examined amounts to about 185,000 square miles, excluding the 6500 square miles of the Falkland Islands. The samples number 112 and are fairly evenly distributed, so that each sample represents on the chart about 1650 square miles of the sea-bottom. This distribution of sampling cannot give any detailed picture of the sea-bottom, but as the region is characterized by great uniformity over large areas the outlines of the nature and configuration of the bottom as sketched in this report may be taken as being approximately correct. Plate II shows the positions of all the stations from which bottom samples were received.

COLLECTION OF SAMPLES

The samples were collected with the conical dredge, which has a mouth 18 in. in diameter and a canvas bag. The dredge has a heavy metal lip which cuts into the bottom so that a large sample is collected from some 6 in. to 1 ft. below the surface of the ground. The dredge is described in detail by Borley (1923).

When the dredge is emptied on deck the sample preserved is taken from the middle of the mass of material turned out, so that the portion of the dredging that was uppermost during hauling, and consequently may have had some of the finer deposits washed out, is rejected. The samples were placed in wide-mouthed screw-capped jars and preserved in spirit.

A haul with the conical dredge was taken as a routine at nearly every station made by the R.R.S. 'William Scoresby' during her survey of the region surrounding the Falkland Islands, and the samples then obtained are the collection forming the subject of this investigation.

ANALYSIS OF THE SAMPLES

For the sake of uniformity, and to afford comparison with other similar investigations, the standard grades of texture used by Allen (1899) and Borley (1923) for the analysis of bottom samples were adopted.

The coarser materials were passed through sieves, and the finer materials were levigated, so that they were divided into grades as follows:

(I)	Large fragments	Material over 15 mm. in diameter.				
(II)	Very coarse gravel	„	10 mm.	and under	15 mm.	in diameter.
(III)	Coarse gravel ...	„	5	„	10	„
(IV)	Medium gravel ...	„	2·5	„	5	„
(V)	Fine gravel ...	„	1·5	„	2·5	„
(VI)	Coarse sand ...	„	1·0	„	1·5	„
(VII)	Medium sand ...	„	0·5	„	1·0	„
(VIII)	Fine sand ...	„	0·1	„	0·5	„
(IX)	Silt	Material under 0·1 mm. in diameter.				

Borley's (1923) method of separating the grades consisted in twice washing the sample to free it from salt, and drying it. A portion of this was then weighed, sifted, usually in water, and the grades produced dried and weighed. A portion of the material passing through the finest sieve was then weighed, moistened and levigated. The resulting grades, except the finest, were dried and weighed. The finest material was rejected and its weight arrived at by subtraction.

In this investigation a technique that avoids the repeated dryings and weighings was devised. The sifting and levigating is combined with the washing, and the grades are weighed once only, and by addition give the total weight of the sample examined.

COARSER MATERIALS

Apparatus

A series of sieves made of perforated zinc with circular holes 15, 10, 5, 2·5, 1·5, 1·0, and 0·5 mm. in diameter were used for separating grades I–VII from each other and from the finer materials. The diameter of the sieve plates was 15 cm.; the sides were 7 cm. high and tapered slightly so that the mouths of the sieves were 16 cm. in diameter. The sieve plates were 1 cm. from the bottom of the sides, which thus rose 6 cm. above them. Round the mouth of the sieves was fitted an india-rubber ring with a groove in it so that it slipped on to the rim. The sieves could be stacked one above the other, each slightly projecting into the one below, the india-rubber rings on the rims making a watertight joint between each (Fig. 2).

Method of use

The sample to be analysed was thoroughly stirred and a portion was placed in the upper one of the stack of sieves. A strong stream of water was then directed through the sieves from above while they were vigorously shaken. The material was thus quickly sorted into its components of various diameters down to 0·5 mm. in diameter, and at the same time it was thoroughly washed free from salt. The material finer than 0·5 mm. in diameter passed through the finest sieve at the bottom of the stack and was discarded. The sieves were then separated, and their contents dried and weighed. The figures obtained, in conjunction with those obtained from the levigator, were combined to show the percentage of the grades in the total sample.

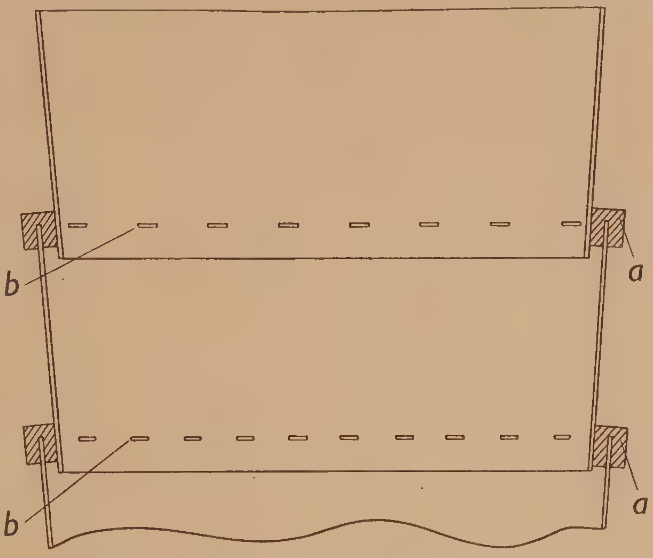

Fig. 2. Sieves stacked one above the other. *a*, rubber ring; *b*, sieve plate.

FINER MATERIALS

A portion of the untreated sample was placed in a sieve with holes 0·5 mm. in diameter. This was then thoroughly agitated in a vessel of water so that all the material finer than 0·5 mm. in diameter passed through into the vessel, and the coarser material of all grades over 0·5 mm. in diameter remained in the sieve. The latter material was then well washed by a stream of water over the vessel, dried and weighed. The finer material that passed through the sieve was then levigated and thus separated into the two finest grades as described below.

Borley (1923) found that in North Sea deposits the separation of grades VIII (fine sand) and IX (silt) could not be readily effected by decantation and so made use of a levigator. The method of levigation was adopted in this investigation as being more accurate and reliable than other methods. Schöne (quoted by Borley) estimated that a vertical current of water travelling at 7 mm. per second would separate spherical quartz particles over 0·1 mm. in diameter from those under 0·1 mm. in diameter. Levigation by a vertical current of this speed was found by Borley to give a very good degree of accuracy (5 per cent) with North Sea deposits, and is the method adopted in this investigation. The levigator used by Borley separated the material analysed into four grades, 0·2 mm. in diameter and over, 0·2–0·1 mm. in diameter, 0·1–0·05 mm. in diameter, and 0·05 mm. in diameter and under. The first two of these grades taken together formed grade "fine sand" and the last two the grade "silt". The levigator used in this investigation separated the material only into the two grades fine sand and silt, containing particles over 0·1 mm. and below 0·1 mm. in diameter respectively.

APPARATUS

The levigator devised for use in this investigation is a development of that used by Borley (1923), which in turn was modified from that of Schöne.

The apparatus (Fig. 3) consists of a tank *a* into which three tubes, *b*, *c* and *d*, pass from below. The tube *c* passes into an inner receptacle, the walls of which are not as high as those of the tank. Tube *b* is the water-supply pipe, tube *c* the waste pipe, and tube *d* the delivery tube. The delivery tube *d* is connected to a down tube *f*. The down tube *f* is connected to a T-piece which in turn is connected to a tube which passes through a hole in bung *j* of receptacle *i* by a short length of tube and two rubber junctions. The upper rubber junction carries a screw clip *e* with a large knurled head, and the lower one carries a spring clip *h*. The side limb of the T-piece is joined to the gauge tube *g*, which is bent through a right angle to bring it vertical. The bung *j* of receptacle *i* has two holes, to one of which is connected down-tube *f*, as described above, while to the other is connected the levigator tube *n* by means of a short length of tube and a rubber junction. At its upper end the levigator tube *n* is joined to the levigator funnel *l* by means of a rubber junction bearing a spring clip. The rubber junctions at the upper and lower ends of the levigator tube are of the same internal diameter as the tube. The levigator funnel *l* has a very short tube, of the same diameter as the levigator tube, and a wide tube *o* passes from the side of the upper part of it. A wide-mouthed funnel *m* is fixed below the outlet of the side tube. The apparatus is levelled so that the tubes are vertical.

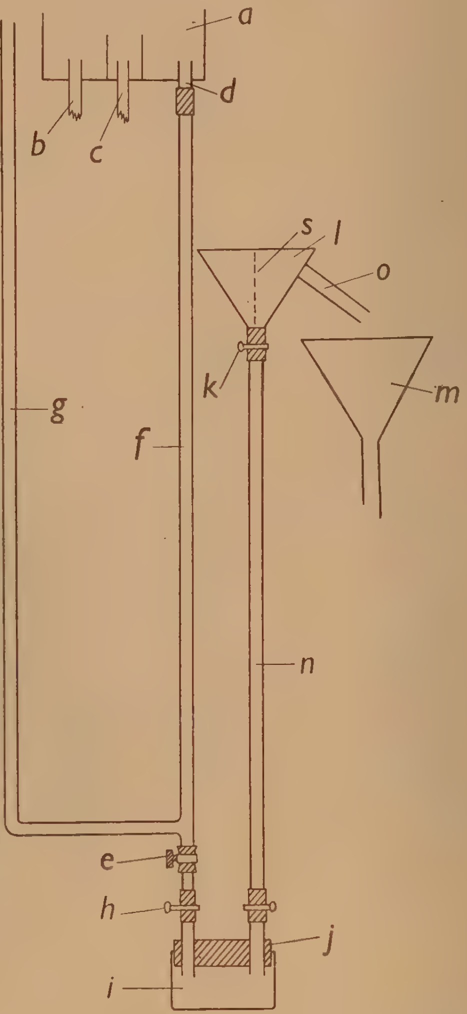

Fig. 3. Levigator. *a*, tank; *b*, supply tube; *c*, waste tube; *d*, delivery tube; *e*, screw clip; *f*, down tube; *g*, gauge tube; *h*, spring clip; *i*, lower receptacle; *j*, bung; *k*, spring clip; *l*, levigator funnel; *m*, wide-mouthed funnel; *n*, levigator tube; *o*, side tube; *s*, removable septum.

Method of use

When the water is turned on at the supply pipe *b* the water rises in the tank to the level of the top of the walls of the inner receptacle. The excess water overflows into the inner receptacle and is conducted away by waste pipe *c*. A constant head of water free from the irregularities of pressure of the supply is thus maintained above the delivery tube *d*. The water flows down the tube *f* into the receptacle *i*, rises up tubes *g* and *n* and fills the funnel *l*, overflowing through tube *o* into funnel *m*. By means of the screw clip *e* the amount of water passing through the apparatus is regulated until the rate of flow in the levigator tube *n* is 7 mm. per second. The tubing used in this investigation was 8 mm. in internal diameter and the rate of flow was adjusted until 253·4 millilitres were delivered at tube *o* in 12 min., this being the amount delivered at a rate of flow of 7 mm. per second. The height of the water in the gauge tube *g* was then marked and the apparatus was thus calibrated for the required rate of flow of water. Owing to the constriction caused by the screw clip *e* just beyond the junction of gauge tube *g* with the down tube *f*, the water-level in the gauge tube varies, on the principle of the Venturi water meter, with the velocity of the water flowing through the apparatus. If the apparatus is to be used for rates of flow of very small amount the gauge tube *g* may be placed at an oblique angle, instead of vertically, so that small changes in level cause comparatively large movements of the meniscus along the gauge tube.

In using the apparatus a weighed filter paper was placed in funnel *m*, the clips *h* and *k* opened and the water turned on, the correct level in the gauge tube being verified. The fine material in the vessel of water, separated from the coarser grades as described above, was well stirred and poured into the levigator funnel *l* and the vessel well washed down into it. The material and water is poured in gently on the side of the movable septum *s*, away from tube *o*, so that swirling does not carry over coarse particles through this tube. Separation begins immediately, the larger particles passing down the levigator tube *n* and accumulating at the bottom of receptacle *i*, while the finer material remains in the levigator funnel *l*, or is carried over into funnel *m* where it is caught on the weighed filter paper.

The amount of material placed in funnel *l* must be such that the filter *m* does not become clogged and overflow before separation is complete. In practice this occurred only on a few occasions with very muddy samples, when the levigation had to be repeated with a smaller quantity of material.

When separation is judged to be complete clips *k* and *h* are closed, when the material in tube *n* settles to the bottom of receptacle *i*. Receptacle *i* is removed and its contents turned out into a funnel containing a weighed filter paper, and well washed down. Levigator funnel *l*, with its rubber junction and clip, is removed and emptied into funnel *m* and well washed down. The filter papers and their contents from funnel *m* and from the funnel containing the material from receptacle *i* are then washed, dried and weighed. This gives the weights of the grades fine sand and silt, and these weights, together with that of the material from which they were separated, which has also been dried and weighed, give the total weight of the sample analysed. From this the percentages of the grades fine sand and silt and the percentage of all the other grades taken together are found. The weights of the other grades, as found from the sieved sample, when added together are therefore equal to the latter percentage of the total. From this can be calculated $\left(\frac{\text{percentage of grades together} \times \text{weight of grade}}{\text{sum of grades}}\right)$ the percentage of each grade in the complete sample.

DISTRIBUTION OF THE GRADES

The results obtained from the quantitative analysis are tabulated and charted to show the distribution of the various grades of material present in the deposits. Each grade is first considered separately and charted according to the percentage in which it is present. Contours are then drawn round areas of similar percentages, thus defining the grounds covered by each grade. Thereafter the texture of each bottom sample as a whole is charted by means of an index number obtained from the proportions of the various grades present in each sample. The grounds covered by deposits of similar texture are defined by contours.

(I) LARGE FRAGMENTS (Plate IV)

(Material 15 mm. in diameter and over)

Most of the region under consideration is free from large fragments, which occur mainly in isolated patches and not in extensive grounds. In the Gulf of San Jorge a greenish grey Tuff (Campbell Smith, W., and Rayner, G., 1934) was picked up in some quantity by the trawl, while off the coast to the south of Cape Tres Puntas and Point Deseado lies a ground in which large fragments are present in quantity varying from 5 to 59 per cent of the deposits. Farther to the east lies a smaller area with 8–10 per cent of large fragments. In lat. 45° 13′ S and long. 59° 56′ 30″ W a patch containing 7 per cent of large fragments lies on the edge of deep water.

Off the southern shores of the Falkland Islands large fragments form up to 48 per cent of the deposits in the shallower water, but the proportion rapidly falls off to 12–15 per cent between the depths of 200 and 300 m., and the grade is absent below 300 m. The stations on the Burdwood Bank show up to 55 per cent of large fragments on the shallower part with the percentage falling to 15 per cent by 200 m. and absent below. The occurrence of outcrops of rock on the Burdwood Bank is regarded by Macfadyen (1933) as probable, from the occurrence of loose fossil Foraminifera in the deposits.

Between the Falkland Islands and the entrance of the Strait of Magellan lies an extensive patch carrying 35–51 per cent of large fragments, while another smaller one lies off the coast of Tierra del Fuego to the south of the entrance to the Strait.

On the line joining the Jason Islands to the south end of the large-fragment grounds south of Point Deseado lie two areas of large fragments. The larger and easternmost one, containing 16–60 per cent of large fragments, lies in the middle of the continental shelf between lat. 50° and 51° S; while the smaller and more westerly one, carrying 1–6 per cent of large fragments, lies between lat. 49° 40′ and 50° S, to the south of the Point Deseado ground.

The remainder of the stations from which large fragments were obtained are few in number and widely scattered over the continental shelf south of lat. 50° S. At St. WS 783 in lat. 50° 02′ 45″ S and long. 60° 10′ W, the sample obtained shows only 1 per cent of large fragments, but two unsuccessful hauls were made at this station before the sample was obtained. In the first two hauls the dredge was bent by rock. This may indicate the presence of large boulders or the outcrop of rock through the deposits. St. WS 825 in lat. 50° 50′ S and long. 57° 15′ 15″ W, with 35 per cent large fragments, lies on the edge of the continental shelf to the north-east of the Falkland Islands.

(II) VERY COARSE GRAVEL (Plate V)

(Material under 15 mm. and over 10 mm. in diameter)

The distribution of very coarse gravel follows closely that of the large fragments, but is rather more widely spread. The grade does not occur in the Gulf of San Jorge, but to the north a small patch lies close to the coast. The large-fragment ground off Cape Tres Puntas and Point Deseado carries up to 9 per cent of very coarse gravel, and the similar ground between it and the Jason Islands carries up to 13 per cent. Two southerly extensions of the latter occur, one carrying up to 8 per cent of the grade, the other 1 per cent.

The south coasts of the Falkland Islands are bordered by an area carrying a small proportion of very coarse gravel, and an extension of the area into deeper water occurs towards the south-west. On the edge of the continental shelf to the north-east of the islands a patch occurs bearing up to 6 per cent of very coarse gravel: this patch coincides with the area of large fragments in the same place. The Burdwood Bank shows an area of this grade extending into deep water towards the north-west, but the grade is absent from the northern slope.

Two small patches of very coarse gravel occur between the Falkland Islands and the entrance of the Strait of Magellan, whilst another occurs off the coast of Tierra del Fuego south of the entrance of the Strait.

Very coarse gravel occurs elsewhere in the region only in isolated patches, particularly towards the edge of the continental shelf north of the Falkland Islands.

(III) COARSE GRAVEL (Plate VI)

(Material under 10 mm. and over 5 mm. in diameter)

This grade occurs over a large part of the region under consideration. A line drawn from Cape San Diego to a point in lat. 50° S long. 60° W and thence to Cape Tres Puntas approximately encloses to the westward the main area of distribution of coarse gravel. A bay in the northern part of this area is free from the grade, as is also a coastal strip extending from Desvelos Bay to Point Gallegos. This large area of coarse gravel does not extend as far east as the Falkland Islands, but west of the islands it carries a higher proportion, up to 18 per cent of the grade, than over the rest of the area where it does not carry more than 5 per cent. North of the area of coarse gravel just described the grade occurs only as isolated patches, small ones in the middle of the continental shelf and at the extreme north, a larger one at the edge of deeper water, while the largest is a coastal strip north of the Gulf of San Jorge.

Coarse gravel forms up to 8 per cent of the deposits on the rough patch at the edge of deep water north-east of the Falkland Islands. It also occurs in small quantity on the rough ground, south of the Falkland Islands, which extends in a south-westerly direction towards deeper water. The grade forms up to 7 per cent of the deposits off the southern entrance of Falkland Sound.

On the Burdwood Bank coarse gravel forms up to 19 per cent of the deposits on the top of the bank, but the proportion drops to only 2 per cent as deeper water is approached to the north.

(IV) MEDIUM GRAVEL (Plate VII)

(Particles over 2·5 mm. and under 5 mm. in diameter)

This grade is widely distributed over the region examined. It is absent only from (i) a belt about 60 miles wide running south-east from the Gulf of San Jorge to lat. 40° S and then turning eastwardly to deep water, (ii) from a coastal strip extending from Point Deseado to Point Gallegos and (iii) from the deeper water below the edge of the continental shelf to the north-east of the Falkland Islands.

The grade occurs over most of the region in small amounts, up to 5 per cent, but a wide tongue in which the proportion is up to 24 per cent extends from the coast of Tierra del Fuego in a north-easterly direction, narrowing to a point short of the Jason Islands. A patch bearing up to 10 per cent of medium gravel lies south of the belt free from the grade that runs south-westerly and westerly from the Gulf of San Jorge.

Deposits off the southern end of Falkland Sound carry 9 per cent of medium gravel, as do those of a patch to the north of West Falkland Island.

The rough patch to the north-east of the Falkland Islands, on the edge of deep water, bears 7 per cent of the grade, whilst the shallower part of the Burdwood Bank shows 16 per cent decreasing to 10 per cent on the slope towards deeper water to the north.

Four isolated patches bearing from 5 to 10 per cent medium gravel occur on the continental shelf south of the Gulf of San Jorge.

The highest proportion of this grade in any of the deposits is only 24 per cent, and if the contour separating the percentages up to 5 per cent from the percentages 6–10 per cent is removed, the wide and even distribution in small proportion of medium gravel over nearly the whole of the region is emphasized.

(V) FINE GRAVEL (Plate VIII)

(Particles over 1·5 mm. and under 2·5 mm. in diameter)

This grade occurs in small proportions over the whole region examined with the exception of the Gulf of San Jorge, a coastal strip from Point Deseado to Point Gallegos, and three isolated patches, one about the middle of the continental shelf east of Point Deseado, another on the edge of deep water farther to the east, and the third in the deep water lying between the Burdwood Bank and Tierra del Fuego.

Fine gravel forms up to 9 per cent of the deposits in coastal belts to the north and south of West Falkland Island, and in two large grounds lying between the Falkland Islands and Patagonia and Tierra del Fuego. It also forms up to 7 per cent of the rough patch to the north-east of the islands. On the Burdwood Bank it is present up to 4 per cent on the shallower parts and increases to 12 per cent towards the deeper water to the north. Three small areas carrying up to 10 per cent of this grade lie on the continental shelf westerly of Point Deseado, while another adjoins the area free from the grade off Point Gallegos.

Fine gravel is nowhere present in greater amount than 12 per cent of the deposits and is both widely and evenly distributed over most of the continental shelf.

(VI) COARSE SAND (Plate IX)

(Particles over 1 mm. and under 1·5 mm. in diameter)

This grade occurs in small amount over nearly the whole region examined, forming not more than 6 per cent of the deposits practically everywhere. It is absent from the Gulf of San Jorge and the area eastward of it, from the coastal belt stretching from Point Deseado to Point Gallegos, from two areas on the continental slope, one north-east of the Falkland Islands and the other east of Point Deseado, and from two small patches near the outer edge of the continental shelf east of the Gulf of San Jorge.

Coarse sand occurs in larger amount, up to 12 per cent of the deposits, off the southern entrance of Falkland Sound, off the west of West Falkland Island, and on the coarse patch north-east of the Falkland Islands. It also occurs on the northern slope of the Burdwood Bank, and in two isolated patches, one about 80 miles east of the entrance of the Strait of Magellan and the other about 40 miles east of Point Gallegos.

(VII) MEDIUM SAND (Plate X)

(Particles over 0·5 mm. and under 1 mm. in diameter)

Medium sand occurs in much larger amount than any of the preceding grades in nearly every part of the region examined. It is absent only from the Gulf of San Jorge and the coastal belt running from Point Deseado to Point Gallegos, and from a patch on the continental slope in lat. 49° 42′ S, long. 54° 14′ 30″ W. Over most of the remainder of the region it occurs in amounts forming up to 10 per cent of the deposits. A large ground extending eastward nearly to long. 64° W from the coast between Point Gallegos and the Strait of Magellan carries a proportion up to 37 per cent towards its eastern end, while a smaller area to the south-east bears up to 15 per cent. A belt round the western shores of West Falkland Island carries amounts up to 36 per cent, while a patch south of East Falkland Island carries 28 per cent of the grade. The rough patch to the north-east of the Falkland Islands on the continental slope carries 22 per cent, while the northern slope of the Burdwood Bank carries 29 per cent of this grade. Five small patches scattered to the north-west of the Falkland Islands, between them and Point Deseado, carry amounts up to 77 per cent, and are the only places in the northern part of the region with more than 10 per cent of medium sand in the deposits.

(VIII) FINE SAND (Plate XI)

(Particles over 0·1 mm. and under 0·5 mm. in diameter)

Fine sand is the characteristic component of the bottom deposits of the whole region and occurs everywhere, usually in large amounts, forming 76–90 per cent of the deposits over more than half the region. It forms 76–90 per cent of the deposits of the continental shelf north of lat. 50° S, with the exception of (i) that part west of long.

65° W off Point Deseado and Cape Tres Puntas, (ii) the Gulf of San Jorge, and an area lying north and west of it as far as long. 64° W, and (iii) a belt following a sinuous course almost half-way across the continental shelf in a north-westerly direction towards Cape Tres Puntas from the edge of the continental slope in lat. 50° S.

East, south and south-west of the Falkland Islands fine sand forms 76–98 per cent of the deposits, excepting a coastal patch south of East Falkland Island and the summit of the Burdwood Bank, while a wedge-shaped area carrying the same amounts extends eastwards from the southern part of the Patagonian coast to long. 64° W.

A belt in which the amount of fine sand is smaller, from 51 to 75 per cent, crosses the continental shelf from the north and north-west parts of the Falkland Islands to the neighbourhood of Point Santa Cruz on the Patagonian coast. In the middle of the continental shelf this belt bears a smaller amount, 14–20 per cent, of fine sand on its northern edge, while closer to the coast there is a patch carrying 22 per cent, abutting on to the coastal region.

The coastal part of the northern section of the region which carries less than 76–98 per cent of fine sand in the deposits carries 51–75 per cent of the grade in the outer zone off the Gulf of San Jorge and to the northwards; while in the Gulf itself and off Cape Tres Puntas and Point Deseado the amount drops to less than 25 per cent. A smaller inner ground off Cape dos Bahias carries 47 per cent, and at the southern extremity of the Point Deseado ground there is a patch carrying 57–62 per cent.

The sinuous tongue which encroaches on to the continental shelf from the east in lat. 49° to 50° S carries 51–75 per cent of fine sand in its outer part, but this amount decreases to 46 and 19 per cent in the central and narrower part and then increases to 56–68 per cent again at its termination half-way across the continental shelf.

The rough patch off the north-east of the Falkland Islands on the edge of the continental slope carries 34 per cent of fine sand in its outer and deeper part: the amount diminishes to 24 per cent in its inner and shallower part.

A broad belt of irregular outline and sinuous course runs from the west of the Falkland Islands, turning in a southerly direction to the coast of Tierra del Fuego, and carries only 26–50 per cent of fine sand. At about its centre in long. 65° W and lat. 51° to 52° S there are two patches in which the amount rises to 58 and 86 per cent respectively, separated by another in which it diminishes to 8 per cent only.

South of East Falkland Island a coastal belt runs east as far as long. 59° W, carrying 30 per cent of fine sand off the southern end of Falkland Sound; the amount drops to 17 per cent in long. 59° W and rises again to 51 per cent as the belt trends away from the coast into deeper water in an easterly direction.

The Burdwood Bank shows only 1 per cent of fine sand in the deposits on the summit, but the amount increases to 19 per cent on the northerly slope.

A small area off Point Gallegos carries only 11 per cent of fine sand, but the amount increases to 35 per cent farther to the east where it meets the wedge-shaped ground carrying a high proportion of fine sand that extends eastwards towards the Falkland Islands.

(IX) SILT (Plate XII)

(Particles under 0·1 mm. in diameter)

Silt occurs in the bottom deposits everywhere in the region under investigation, but over most of it is present in small amounts. South of lat. 46° 30′ S it forms up to 5 per cent of the deposits of the continental shelf, but north of this latitude lies a wide belt where it is present in larger amounts, as it is also on the eastward part of the continental shelf north of the Falkland Islands.

The Gulf of San Jorge contains a very high proportion of silt, 94 per cent, as does a coastal strip off Point Gallegos with 89 per cent. East and north of the Gulf of San Jorge there lies a wide area stretching as far east as long. 62° 30′ W which carries up to 45 per cent of silt. From the eastward edge of this area and extending in a southerly direction to the edge of the continental shelf lies an area carrying up to 10 per cent of silt. Towards the southern end of the latter area and stretching in from the continental slope is a large patch carrying 17 per cent in its northern part and 83 per cent in its southern part. North of the former area and eastwards on the continental slope the proportion of silt in the deposits drops again to 3–5 per cent.

North of the Falkland Islands an area bearing up to 33 per cent of silt extends up the continental slope and on to the continental shelf as far west as long. 62° 50′ W. Towards its north-west extremity the amount of silt in this area drops to 6 per cent, while on its south-eastern border lies a patch in which the amount drops to 10 per cent. A belt containing 12 per cent of silt runs in from this area towards the north coast of West Falkland Island.

In the bay of deep water north-west of the Burdwood Bank lies an area in which the amount of silt in the deposits rises to 23 per cent, while on each side of the entrance of the Strait of Magellan there is a patch containing silt up to 14 per cent in the northern and up to 6 per cent in the southern one.

Silt up to 13 per cent of the deposits occurs in a small patch to the north-west of the area extending in westwards from the continental slope north of the Falkland Islands.

Amounts higher than 5 per cent of silt in the deposits occur elsewhere only as a line of patches extending north-west from the Jason Islands towards Point San Julian. A coastal patch off the Jason Islands carries up to 25 per cent of the grade; farther to the north-west two patches lie near the middle of the continental shelf and carry 6 and 7 per cent of silt respectively, while off Point San Julian a patch carries 6 per cent of silt in the deposits.

Consideration of the distribution of the deposits based on the texture of each sample as a whole is deferred until a description of the types of deposit found in the region has been given.

TYPES OF DEPOSIT

Dried samples from all the stations were assembled and arranged into twenty-nine types, which fall into six well-defined groups. The groups are here designated by an initial letter, and the types within the groups by the addition of a numeral to the initial (e.g. A4).

The types are described by their composition and colour and to a less degree by their texture, but identification of the minerals composing them has not been attempted. The description does not in all cases correspond with that given in the station list and noted at the time that the station sounding was made. This is largely due to the fact that the samples change colour, many of them considerably, in drying. Samples that are light greenish grey for example when dry appear dark grey, almost black, when wet; others change similarly.

The groups are sharply defined from each other and the allotment of any given sample to its group is obvious. The types within the groups, however, are not in all cases so easily separated and tend to merge into one another through intermediate types. A strong family resemblance running through all the groups with the exception of group A, and occurring in nearly all samples, is the green colour of the silt. This varies from brownish and greyish green, through dark and light greens to yellowish green. It appears, in many instances at least, to be due to a glauconitic substance: glauconite has been identified by Macfadyen (1933) in some samples of bottom deposits from the Burdwood Bank.

Groups recognized:

Group A. Chief components, shell and coral fragments. Contains five types: samples from eight stations.

Group B. Chief component, white or yellowish-white sand. Contains four types. Samples from ten stations.

Group C. Chief component, brown sand. Contains seven types. Samples from twenty-six stations.

Group D. Chief component, greyish-brown sand. Contains five types. Samples from twenty-six stations.

Group E. Chief component, grey sand and silt. Contains four types. Samples from fifteen stations.

Group F. Chief components, green or greyish-green sand and silt. Contains four types. Samples from twenty-six stations.

DESCRIPTION OF THE TYPES

GROUP A. SHELL AND CORAL FRAGMENTS

TYPE A1. Medium grades consist of fragments of coral (Turbinolidae) with a smaller proportion of clear angular sand grains, shell fragments and grey gravel. Silt yellow, appearing to consist of coral detritus. Two samples, WS 93, WS 802.

TYPE A2. Medium grades consist of coral and shell fragments with dark grey gravel. Large dark grey pebbles and echinoderm spines in the coarser grades. Fine sand and silt yellow, consisting of coral and shell detritus. One sample, WS 86.

TYPE A3. Medium grades consist of coral and shell fragments; a large proportion of whole and broken bivalve shells (*Pecten* and clam types), dark grey pebbles and gravel in the coarser grades.

Some white sand grains in the finer grades. Silt yellow to yellowish green. Two samples, WS 83, WS 246 (192 m.).

TYPE A4. Medium grades consist of shell fragments; grey stones, pebbles and gravel, with large fragments of shell (clam, *Pecten* and brachiopod), especially in WS 825, in the coarser grades. A large admixture of white and clear sand grains in the finer grades, which are similar to those of group B. Silt buffish grey. This type consists of almost equal parts of types A1 and B1. Three samples, WS 84, WS 228, WS 825.

TYPE A5. Finer grades consist of shell, coral, and calcareous polyzoan fragments; brown and grey stones much encrusted with calcareous Polyzoa, small bivalve shells, large fragments of Polyzoa, grey and brown gravel in the coarser grades. Silt yellowish buff. One sample, WS 88.

GROUP B. WHITE AND YELLOWISH-WHITE SANDS

TYPE B1. A fine yellowish-white silver sand with very few dark grey grains. Silt yellow. One sample, WS 823.

TYPE B2. A fine yellowish-white silver sand with a greenish tint owing to the green or greyish-green colour of the silt. Some small shell fragments and dark and light grey sand grains. In WS 230 some small transparent green angular fragments. Six samples, WS 227, WS 229, WS 230, WS 781, WS 782, WS 824.

TYPE B3. Fine yellowish-white silver sand with a greenish tint owing to the green or greyish-green colour of the silt, differing from type B2 in the larger proportion of large shell fragments and dark grey stones and pebbles. In the finer grades a large proportion of transparent greenish grains. One sample, WS 248.

TYPE B4. Fine yellowish-white silver sand conspicuously speckled with an admixture of dark grey and black grains, and with a small proportion of transparent green grains. At WS 246 (267 m.), pinkish grey pebbles and some brown and yellow gravel. Silt yellowish brown to greenish brown. Two samples, WS 246 (267 m.), WS 250.

GROUP C. BROWN SANDS

TYPE C1. Light brown speckled sands, with a few shell fragments in the coarser grades, and an admixture of white, black and grey grains in the finer grades. Silt brown to brownish green. Six samples, WS 219, WS 220, WS 787, WS 796, WS 808, WS 809.

TYPE C2. Darker brown sands of less speckled appearance and finer texture than type C1. A few small bivalve shells and worm tubes in the coarse grades of some samples, and a small admixture of black and white grains in the finer grades. A few Foraminifera in some samples. Silt yellowish to brownish green. Six samples, WS 235, WS 765, WS 771, WS 774, WS 792, WS 801.

TYPE C3. Light brown sands with a large proportion of clear and white grains and a small proportion of dark ones. Shell fragments and brown pebbles in the coarser grades. Silt brown. Three samples, WS 96, WS 222, WS 772.

TYPE C4. Darker brown speckled sands with a large proportion of black grains as well as white ones. Texture coarser than the preceding types of group C. Some samples with shell fragments, or worm tubes made of sand, in the coarser grades. Silt brown to brownish green. Four samples, WS 94, WS 226, WS 240, WS 806.

TYPE C5. Darker brown sands with a large proportion of black grains and fewer white ones. Texture coarser than type C4, with black, grey, brown and yellow gravel. In the coarser grades dark grey stones, coral, and calcareous polyzoan fragments, worm tubes both calcareous and made of sand or gravel, small shells and echinoderm spines. Four samples, WS 95, WS 799, WS 807, WS 837.

TYPE C6. Brown sands with a large admixture of calcareous matter producing a conspicuous speckling of white. Some brown and grey pebbles in the coarser grades, with coral and calcareous polyzoan fragments, echinoderm spines, shell fragments, and worm tubes made of sand. A large proportion of black grains in the finer grades, and many white foraminiferan shells which give the characteristic speckling to the type. Silt light brownish green. Two samples, WS 804, WS 838.

Type C7. Light brown sand with an admixture of clear transparent angular grains, and a small proportion of pink grains in the finer grades. The coarser grades, which form about half of the type, consist of irregular and angular light brown stones, large fragments of shell, calcareous worm tubes, with some echinoderm spines and coral fragments. Silt grey with a slight green tint. One sample, WS 221.

GROUP D. GREYISH-BROWN SANDS

Type D1. Fine greyish brown sands, of even rather than speckled appearance, though composed of a mixture of brown, black or dark grey, and white grains, with a slight greenish tint owing to the colour of the silt. Small bivalve shells or worm tubes made of fine sand in the medium grades of some samples; some Foraminifera in the finer grades of others. Silt greyish and brownish green to green. Eight samples, WS 78, WS 79, WS 217, WS 227, WS 764, WS 785, WS 786, WS 793.

Type D2. Darker and coarser greyish-brown sands composed of black, dark grey, brown and yellow grains. Large worm tubes made of medium and fine gravel, calcareous worm tubes and coral in the coarse grades of WS 849. The coarser grades dark grey, light grey and brown gravels. Silt yellowish to greyish green. Three samples, WS 80, WS 243, WS 849.

Type D3. Dark greyish-brown sands with marked speckling. Greyer and less brown than the preceding types of group D. Dark grey, brown, and yellow or white grains are the chief components, with a few Foraminifera in the finer grades. Worm tubes made of sand and gravel, calcareous worm tubes, calcareous polyzoan fragments, gastropod shells and light brown pebbles are present in the coarser grades of WS 811. Silt yellowish brown, through brown to greyish green. Five samples, WS 77, WS 242, WS 811, WS 814, WS 817.

Type D4. Dark greyish-brown sands of more even colour than type D3, with a higher proportion of coarser grades consisting of dark grey and brown stones and pebbles, coral and broken bivalve shell. Some angular fragments of brown stone in WS 848, and large worm tubes made of gravel in WS 800: Foraminifera are conspicuous in the finer grades of WS 91. Silt yellowish to greyish brown. Four samples, WS 91, WS 92, WS 800, WS 848.

Type D5. In this type the gravels and large fragments preponderate in quantity over the finer grades. The finer grades are dark greyish-brown sands of rather even tint, the coarser grades consisting mainly of dark and light grey, brown, and yellow stones and gravels. Shell fragments, coral, calcareous encrusting Polyzoa and worm tubes, and worm tubes made of gravel, occur in the coarser grades. Silt greenish yellow to greenish brown. Six samples, WS 225, WS 798, WS 803, WS 805, WS 816, WS 850.

GROUP E. GREY SANDS AND SILTS

Type E1. Very fine sandy muds of even, light grey colour. No grades above fine sand occur, and silt preponderates except in WS 776 where it forms about half of the sample. WS 777 is a stiff grey clay which dries to solid lumps and not to powder, while the silt of the other examples of the type dries into hard cakes, grey in colour, which bind the fine sand. Three samples, WS 776, WS 777, WS 812.

Type E2. Fine muddy sands of light speckled grey colour. The sand grains are mostly black or dark grey, and white, with a small admixture of brown grains not sufficient to give their tint to the type. There are a few grey and yellow pebbles in the coarser grades. Silt greyish green to yellowish green. Three samples, WS 90, WS 218, WS 814.

Type E3. Fine muddy sands of even dark grey colour. Dark and light grey, brown and yellow stones and gravel occur in the coarser grades of some samples; coral, both Turbinolid and an arborescent form, shell fragments, papery worm tubes and echinoderm spines in others. The finer grades consist of dark and light grey grains with some brown, yellow, or white grains. Foraminifera are present in some numbers in WS 833, while fine fragments of coral form a conspicuous part of the finest grades of WS 766. Silt grey to greyish green. Eight samples, WS 89, WS 238, WS 245, WS 762, WS 766, WS 788, WS 833, WS 834.

Type E4. Light grey gravel composed of irregular but slightly rounded fragments of soft grey stone or very hard grey clay, with some greyish-brown pebbles and gravel in the coarsest grades. Bivalve, gastropod, and brachiopod shells and fragments are numerous in the medium grades. Silt yellowish brown. This type is quite distinct from all the other types of group E. One sample, WS 841.

GROUP F. GREYISH-GREEN SAND AND SILT

Type F1. Medium to dark coloured greyish-green muddy sands of fine texture, consisting almost entirely of grades fine sand and silt. A few samples have small shell fragments and grey or brown gravel in small proportions in the coarser grades. The finer grades are grey to greyish green, with some admixture of white grains in some cases. Silt greyish green through green to light yellowish green. Thirteen samples, WS 99, WS 211, WS 212, WS 214, WS 232, WS 236, WS 244, WS 756, WS 773, WS 790, WS 791, WS 821, WS 839.

Type F2. Greyish-green muddy sands lighter than those of type F1 by reason of the larger admixture of yellow and white grains, as well as lighter grey and greyish-green grains. Fine in texture, with a small proportion of shell and coral fragments, dark and light grey, white, and yellow gravel in the coarser grades of some samples. Foraminifera occur in small numbers in some samples. Silt dark greyish green through green to yellowish green. Nine samples, WS 76, WS 210, WS 239, WS 775, WS 783, WS 784, WS 810, WS 819, WS 820.

Type F3. Darker greyish-green sands of coarser texture than type F2 with coral (Turbinolid) forming a large proportion of the coarser grades in which there are also some grey pebbles. The finer grades are mixed with coral detritus. Silt dark greyish green. Two samples, WS 215, WS 818.

Type F4. A light greyish-green type of coarse texture with some grey and brown stones and a high proportion of gravels composed of grey, greyish-green, brown, and yellow pebbles. Small fragments of shell and echinoderm spines occur, while Foraminifera are conspicuous in the finer grades. Silt green. One sample, WS 97.

DISTRIBUTION OF THE TYPES

The types described above are distributed in well-defined areas mostly covering wide expanses of the sea-bottom. Plate XIII shows the distribution of the types by group, and the occurrence of the various types within the groups is described below.

GROUP A

The distribution of the types assigned to group A is confined to the southern part of the region examined. They occur as a coastal belt off the west and south shores of the Falkland Islands from a little north of the Jason Islands to long. 58° 30′ S on the south coast, but not in Falkland Sound. A patch extends in a north-easterly direction from the north coast of East Falkland Island to the edge of the continental slope. In the northern part of the coastal belt the types are A1, passing through A3 off the south coast of West Falkland Island and Falkland Sound to A4 off the south coast of East Falkland Island. The patch to the north-east of the islands is entirely A4.

On the Burdwood Bank there is a patch on the northern slope consisting of type A2. Farther to the west, north of the western extremity of Tierra del Fuego, lies another patch of deposits assigned to this group and consisting of type A5.

GROUP B

The distribution of this group, like that of group A, is confined to the southern part of the region, and occurs only to the north-east, east and south of the Falkland Islands. A line extending in a north-easterly direction from long. 59° 30′ W off the north coast of West Falkland Island forms the north-eastern boundary of the area, while a line extending in a south-easterly direction from the edge of the coastal belt of deposits of group A, south of the western extremity of West Falkland Island, forms the south-eastern boundary. Within these boundaries deposits of group B cover the continental slope and the coastal shelf, except for the coastal belt of group A deposits off the south coasts of the Falkland Islands and the patch of group A deposits lying on the continental shelf to the north-east of East Falkland Island. They also occur in the southern end of Falkland Sound. The northern part of the area as far south as lat. 51° 30′ S consists entirely of type B2, which appears also to form the deposits on the continental shelf east of East Falkland Island. On the continental slope south and east of the Falkland Islands type B4 predominates, while a patch of type B3 occurs just below the 200 m. contour west of Beauchêne Island. The deposits in the eastern end of Falkland Sound consist of type B1.

GROUP C

Deposits of group C cover a large area of the continental shelf. At the north of the region examined they cover the continental shelf to the edge of the continental slope nearly as far south as lat. 45° S, with the exception of a broad coastal belt south of Delgada Point. These deposits are of the type C2, with the type C3 occurring at the south-east point of the area.

A large area stretching west and north from the coastal belt of group F deposits between Point Deseado and Point Santa Cruz covers about half of the continental shelf in its southern part, and about three-quarters of it in its northern part. At about its centre it reaches as far east as the edge of the continental slope. Types C1 and C2 occupy all the northern half of the area and the area on the western or coastal part of the southern half. The eastern or outer part of the southern half consists of types of higher index number, type C5 occurring to the north and C4 to the south. Type C6 occurs at the extreme south-east point of the area, while type C7 intrudes to the east on to the type C1 and C2 portions of the area in lat. 48° 20′ S, long. 65° 20′ W. North of this lies a small area of type C3.

A third area bearing deposits of group C stretches north-east from the coast of Tierra del Fuego as far as lat. 51° 40′ S, long. 65° W, separated from the entrance of the Strait of Magellan by a coastal belt of group E deposits. The index number of the types increases from type C4 in the northern part of the area through type C5 in the central part, to type C6 in the southern part.

GROUP D

The main area covered by deposits of group D lies in the southern part of the region under consideration. Between Point San Julian and the entrance of the Strait of

Magellan a belt of groups E and F lines the coast: outside this belt an extensive area of deposits of group D stretches eastward as far as long. 65° W. Here it sends a wide limb in a southerly direction towards Staten Island, outside the areas covered by deposits of groups C and A, bounded on the east approximately by the 200 m. contour at the edge of the bay of deeper water extending in a northerly direction between the Falkland Islands and South America. North of this southerly-directed limb the area extends to the east to about long. 61° 40′ W, where it approaches closely the deposits of group A off the Jason Islands. Here a narrower neck joins it to an area occupying the centre of the continental shelf between lat. 48° 20′ and 50 S. The northern part of this latter area consists of type D 4, the remainder of type D 1. The narrow neck joining it to the rest of the area covered by deposits of this group consists of type D 5 which also occurs in a northerly directed extension of the main area and along the adjacent eastern border. Type D 4 forms most of the southerly directed limb, with type D 3 appearing on the east and type D 5 on the west of its northern half.

Types D 1 and D 2 occupy the central part of the area, type D 1 occurring again near the coast between Point Gallegos and Point Santa Cruz; the intermediate portion is covered by deposits of types D 3 and D 4.

Another area covered by deposits of group D lies on the eastern third of the continental shelf between lat. 44° 30′ and 46° 40′ S. Between 46° and 46° 40′ S it bends towards the south-east and extends out to the edge of the continental slope. The deposits of this area consist entirely of type D 1. A further small area covered by deposits of group D lies east of Cape Tres Puntas and stretches over the continental shelf as far as the area covered by deposits of group F. It consists of type D 5.

GROUP E

Deposits of group E occur in scattered areas, of smaller extent than those of most of the other groups, in all parts of the region. The largest area covered by deposits of this group lies off the coast between Delgada Point and Cape Tres Puntas, including the Gulf of San Jorge. The northern part of this area consists of deposits of type E 3, while the Gulf of San Jorge and the area to the east of it consist of deposits of type E 1. East of the Gulf of San Jorge at the edge of the continental shelf an area of deposits of group E occurs; on the continental shelf the type is E 3, whilst on the continental slope it is E 2.

A coastal belt running from Point Santa Cruz to San Sebastian Bay in Tierra del Fuego consists of deposits of type E 1 as far south as Cape Virgins, where type E 2 appears, while the remainder off the entrance of the Strait of Magellan consists of type E 3.

On the Burdwood Bank deposits of the type E 4 cover the western part of the summit and adjoin deposits of type E 2 lying on the western slope.

Two isolated patches of deposits of type E occur, one at the edge of the slope to deeper water between the Falkland Islands and Tierra del Fuego in lat. 52° 40′ S, long.

63° 40′ W, the other towards the outer part of the continental shelf in lat. 48° 30′ S, long. 61° 50′ W, both of type E3.

GROUP F

An extensive area of deposits of this group covers the deep-water region between the Burdwood Bank and the Falkland Islands, and the Burdwood Bank and Tierra del Fuego. It covers the floor of the bay of deep water stretching north between the Falkland Islands and South America, and becomes constricted to a narrow neck west of the Jason Islands. To the north it opens out widely again and covers the continental shelf north of the Falkland Islands east of long. 62° W as far north as lat. 48° 20′ S. From this point the area stretches south to the north coast of West Falkland Island. To the north-east deposits of group F cover the continental slope as far north as lat. 47° S, where they again extend up on to the continental shelf as far west as long. 61° 30′ W.

In the portion of the area north of the Falkland Islands, the eastern parts on the continental slope and on the continental shelf north of West Falkland Island are covered by deposits of type F1, except in lat. 47° 40′ S where a patch of type F3 lies on the continental slope. The remainder of this area on the continental shelf is covered by deposits of type F2, while a patch of type F4 occurs at its north-west corner in lat. 49° S.

The narrow part of the group F area west of the Jason Islands consists of deposits of type F2, as does the central and deeper part of the area between the Falkland Islands and Tierra del Fuego. The northern part of the deep water bay and its eastern and western slopes are covered by deposits of type F1, while a patch of type F3 lies on the western slope adjacent to the patch of type E3.

A wedge-shaped area of deposits of group F lies in the middle of the continental shelf between latitudes 44° and 47° S, the point of the wedge being directed southwards. The deposits are of type F1 except at the pointed southern end of the area where they are of type F2.

The third area covered by deposits of this group is a coastal belt running from Point Deseado to Point Santa Cruz, consisting of type F2.

DISTRIBUTION OF THE DEPOSITS BY THE TEXTURE OF THE SAMPLES AS A WHOLE

Having detailed the distribution of the various component textures and types of the bottom deposits, the division of the region into grounds based on the texture of each sample as a whole is now considered. The results are shown in Plate XIV.

In order to arrive at a value for the texture of the deposits which may be plotted comparatively the following procedure is adopted. In each sample the percentage of each grade of material is multiplied by the minimum diameter of the particles occurring in the grade, with the exception of the silt grade. The silt grade is omitted as the minimum diameter of the particles composing it is infinitely low. The figures for each grade thus obtained are added together and divided by 100, the resulting index number being the "representative number" of the sample. Thus a sample containing only large fragments would have a representative number of 15, while one containing only silt would have a representative number of 0. All other proportions of the grades are represented by the numbers between 0 and 15, the representative number increasing in value as the coarseness of the texture increases. The samples are then referred to the grade containing particles whose diameter in millimetres corresponds with the representative number. Thus a sample with representative number 0·31 is referred to grade *fine sand*, which contains particles 0·1–0·5 mm. in diameter, whilst a sample with representative number 7·61 is referred to grade *coarse gravel*, which contains particles 5–10 mm. in diameter. Samples with representative numbers below 0·1 are classed as silt. The deposits are then plotted on the chart according to the grades to which they are assigned.

The finest two grades, fine sand and silt, cover the greater part of the region considered and form extensive grounds, while the coarser grades occur in smaller grounds and patches. A line running east from Cape Tres Puntas to the edge of the continental shelf, and then turning southerly and following the edge of the shelf to the north-east of the Falkland Islands, where it turns eastward again, divides the two main grounds of the region, the silt grounds lying to the north and east, and the fine sand grounds to the south and west of the line.

THE SILT GROUNDS

The silt grounds, about 60,250 square miles in area, are composed of deposits of the groups C, D, E and F. Group E deposits occur in the western part, those of group F on the continental slope and in the middle of the continental shelf. Deposits of group C cover the northern part and a wedge-shaped area at the centre of the continental shelf, while those of group D lie to the east of this latter area. North-east of the Falkland Islands between lat. 50° and 51° S the silt ground extends over the edge of the continental slope on to the continental shelf and reaches in towards the north coast of the Falkland Islands at the northern end of Falkland Sound. This part, both on the continental slope and shelf consists of deposits of group B.

Smaller coastal silt grounds about 800 square miles in area lie off Point San Julian and Point Gallegos, the former with deposits of group F, the latter of group E. Another small area of about 850 square miles lies on the continental slope west of the deep water lying north-east of the Burdwood Bank. Its deposits belong to group F. Grounds of coarser texture lie in smaller areas within the main silt ground as detailed below.

COARSER GROUNDS WITHIN THE SILT GROUNDS

There is a coastal belt of fine sand 2800 square miles in area, with deposits of group E, between Cape dos Bahias and the Valdes Peninsula, while at the edge of the continental slope between lat. 45° and 47° S lies a ground of fine sand of about 1200 square miles area. Its deposits are of group E to the north, and of group D at the south, with a patch of 750 square miles of medium sand of group E midway between the northern and southern extremities.

THE FINE SAND GROUNDS

The fine sand grounds of the southern and western parts of the region examined cover an area of about 106,500 square miles and carry deposits of all the groups recognized. Deposits of group A occur off the west of West Falkland Island, of group F north of this and in deeper water west and south of the Falkland Islands and the Burdwood Bank, and off the coast north of Point Santa Cruz. Between lat. 47° 30′ and 48° 30′ S deposits of type C occupy the continental shelf between long. 61° and 64° 40′ W. This group appears again a little to the south-west on the continental shelf nearer the coast between long. 63° and 67° W and lat. 49° and 50° 10′ S. A further area covered by deposits of group C lies on the continental shelf east of the Strait of Magellan and Tierra del Fuego east of lat. 65° W. Its eastern boundary coincides with that of the grounds of coarser texture on the edge of deeper water as described below. Deposits of group D occupy a central area on the continental shelf between lat. 48° 30′ and 50° S, and also the area of fine sand grounds between lat. 50° 10′ and 52° 10′ S and long. 63° 20′ and 68° W. Deposits of group E occur in a coastal belt between Point Santa Cruz and the entrance of the Strait of Magellan, and on the western slope of the Burdwood Bank. The area to the west of the Falkland Islands and the continental slope to the south of them is covered by deposits of group B.

COARSER GROUNDS WITHIN THE FINE SAND GROUNDS

The find sand grounds are interrupted by many coarser grounds. North-east of the Falkland Islands they are separated from the silt grounds by a ground of coarse gravel about 1360 square miles in area on the continental shelf, from which a ground of medium sand about 400 square miles in area extends down the continental slope into the fine sand ground. The deposits of both these grounds are of group A.

A coarser ground about 5600 square miles in area, extending eastwards from Cape Tres Puntas as far as long. 64° 40′ W and southwards as far as lat. 49° S, consists of various grades of gravel. Off Cape Tres Puntas an area of about 1100 square miles consists of medium gravel of group D. It adjoins an area of 950 square miles of fine gravel off Point Deseado. Off Nodales Bay lies an area of about 850 square miles of very coarse gravel, south of which lies an area of about 2300 square miles of coarse gravel. The coastal portions of the last three grounds consist of deposits of group F, while in the outer parts the deposits belong to group C, as do those of an area of about 470 square miles of medium gravel lying at the south-eastern extremity of these grounds of coarser grade.

A little more than half-way between the last grounds and the edge of the continental shelf lies a ground of finer texture. It extends in approximately a north-westerly and south-easterly direction between lat. 48° and 49° 10′ S, and is about 2250 square miles in area. The northern fourth of it, 470 square miles in area, consists of medium sand of group C, the second fourth of about 560 square miles of fine gravel of group D, the third fourth of about 660 square miles of coarse sand of group E, and the southern fourth of about 560 square miles of medium gravel of group F.

To the north-east of this ground and lying on the continental slope at the junction of the silt and fine sand grounds lies a patch of about 400 square miles of very coarse gravel of group F.

An extensive ground about 12,000 square miles in area and of coarse texture lies between the Falkland Islands and the coasts of Patagonia and Tierra del Fuego. It runs from the neighbourhood of Cape San Diego in a north-easterly and north-north-easterly direction as far as lat. 50° S. The middle part of it is a comparatively narrow belt, while the northern and southern ends expand to form wider areas. Most of the northern area, of about 2400 square miles, consists of coarse gravel, of group D at the eastern and western extremities and group C in the centre. The northern half of the belt, about 2000 square miles in area, is of medium gravel of group D. The southern half of the belt and most of the southern area, about 4700 square miles, consist of coarse gravel, of group D on the continental shelf, while on the continental slope deposits of group E occur in the northern part and of group F in the southern. An area of about 900 square miles of medium gravel of group A occurs at the southern extremity, and a smaller area of about 200 square miles of coarse sand of group D lies at the western border of the belt in lat. 52° S.

To the west of the northern area of the preceding ground lies another gravel ground, about 2250 square miles in area, between lat. 50° and 51° S and long. 65° and 66° W. It is wedge-shaped, with its point directed westwards, while its base towards the east is deeply indented. The western part, 650 square miles in area, consists of coarse gravel of group D, the eastern part of 1600 square miles of fine gravel, of group D in the south and group C in the north.

A small ground of medium gravel, about 350 square miles in area, lies about 40 miles east of Point Gallegos: its deposits belong to group D. A ground of about 450 square miles of very coarse gravel of group E lies off the coast between the entrance of the Strait of Magellan and San Sebastian Bay. About 60 miles east of this ground, half-way between it and the extensive gravel grounds west of the Falkland Islands, lies a small patch of about 650 square miles of coarse sand of group C.

A gravel ground lies off the south coasts of the Falkland Islands and extends down the continental slope at its eastern and western ends. Its area is about 3250 square miles. The western part of the ground, 980 square miles in area, off West Falkland Island consists of medium gravel and extends over the continental slope. The eastern part, about 1850 square miles in area, off the southern end of Falkland Sound and East Falkland Island consists of coarse gravel, but does not extend down the continental slope nor into Falkland Sound where the ground is fine sand of group B. All the portion of this ground on the continental shelf carries deposits of group A, but where it extends over to the continental slope the deposits are of group B. The eastern extremity of the ground extends down the continental slope south of East Falkland Island and consists of fine gravel of group B.

The Burdwood Bank shows a ground exceeding 1000 square miles in area of very coarse gravel of group E on its summit, and one of about 850 square miles of medium gravel of group A on its northern slope.

The main features of the texture of the bottom deposits shown by charting the deposits according to the grade are the two chief grounds, silt to the north and east, fine sand to the south and west. Extensive but smaller grounds of various coarser grades of sand and gravel occupy large areas of the continental shelf west of long. 60° W and south of lat. 47° S. Though the areas covered by the various types of deposit do not coincide with the grounds grouped according to texture, it is noticeable that the contours delimiting deposit types frequently coincide in part of their course with those delimiting the grounds.

DISCUSSION

The sparseness of sampling in the region examined is such as to preclude any detailed discussion of the causes of the distribution of the bottom deposits. The entire region is characterized by the presence of enormous masses of fine sand and silt. A line running first in a northerly and then in a north-westerly direction from the Falkland Islands to the South American coast separates the silt grounds on the north and east from the fine-sand grounds to the south and west. The currents and prevailing winds of the part of the South Atlantic comprised in the region examined travel approximately from south-west to north-east; to these agencies and to the heavy swells which prevail the segregation of the silt grounds to the north and east of the region is no doubt due. A chain of coarser grounds also extends in unbroken line for nearly 300 miles from the eastern extremity of Tierra del Fuego in a north-north-easterly direction as far as lat. 50° S. Thereafter the line is interrupted, but patches of coarse material lie on the course of the line for another 300 miles to lat. 45° S. Grounds of coarser texture also extend in a north-easterly direction from the north-east corner of the Falkland Islands. It is possible that the position of these grounds, extending in a south-westerly to north-easterly direction, is correlated with the currents and prevailing winds of the region which travel in the same direction. In support of this it is noticeable that the contours enclosing the areas covered by the different types of deposit (see Plate XIII) in many cases run in a south-westerly to north-easterly direction. This is particularly marked in the area covered by deposits of group F which extends across the region from south-west to north-east west of the Falkland Islands. On the other hand, the coarse grounds stretching across the area in a north-easterly direction may also be correlated with rock outcrops occurring there.

It appears probable that some at least of the deposits are being formed *in situ* on the sea bottom and are not derived from the land or other regions. On the Burdwood Bank, Macfadyen (1933) has deduced the occurrence of rock outcrops from the presence of fossil Foraminifera in the deposits. The same deposits also contained portions of the rock from which the fossils had been washed out. The occurrence of glauconite in the

Burdwood Bank deposits is traced by the same author to the disintegrating rock, the glauconite being of fossil and not of recent origin. An area similar to the Burdwood Bank in this respect, lying in the south-west of the region considered, in which outcrops of rock are being disintegrated by attrition and otherwise, would act as a reservoir from which materials would be transported by currents and drifts to the north-east and segregated into finer and finer grades the farther they travelled from their point of origin. The glauconitic silts of the northern part of the region may therefore owe their presence to some such combination of circumstances.

No very large rivers discharge into the region under consideration, but the deposits in the coastal belts are doubtless in large part derived from the land. In the Gulf of San Jorge the deposits have been shown by Campbell Smith and Rayner (1934) to be in part of volcanic origin. The deposits contain a high proportion of finely divided volcanic glass and feldspar derived from the volcanoes of the Andes and, together with the clay of non-volcanic origin, the materials are in process of forming a sedimentary volcanic tuff. The white sands occurring off the Falkland Islands would appear to be of terrigenous origin and to be derived from the quartzite rocks of the islands.[1] A deposit of similar type north of the extremity of Tierra del Fuego may be of much the same origin, while the deposits of like type on the north slope of the Burdwood Bank would indicate an outcrop of quartzite rock there, similar to the outcrops of shales found on the bank farther to the east by Macfadyen.

SUMMARY

This report describes the marine deposits of the Patagonian continental shelf from the standpoint of providing data regarding the habitats of the bottom-living fauna of the region.

The topography of the sea-bottom of the region is described. Methods of separating the deposits into their component grades of texture, and an improved form of levigator for separating fine materials are described. The distribution of the various grades of material in the deposits is given in detail.

Twenty-nine types of deposit, falling into six groups, were found: their characters and distribution are described.

Finally the region is divided into grounds according to the texture of the deposits. The distribution of the grounds, and the types of deposit found on them, are described.

Though fuller data are required for a detailed discussion of the causes of the present distribution of the deposits, the probable effect of the currents of the region in segregating finer materials towards the north is pointed out.

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[1] The quartzite rocks of the Devono-Carboniferous are shown by Baker (1924) to be characteristic of West Falkland Island and the north part of East Falkland Island.

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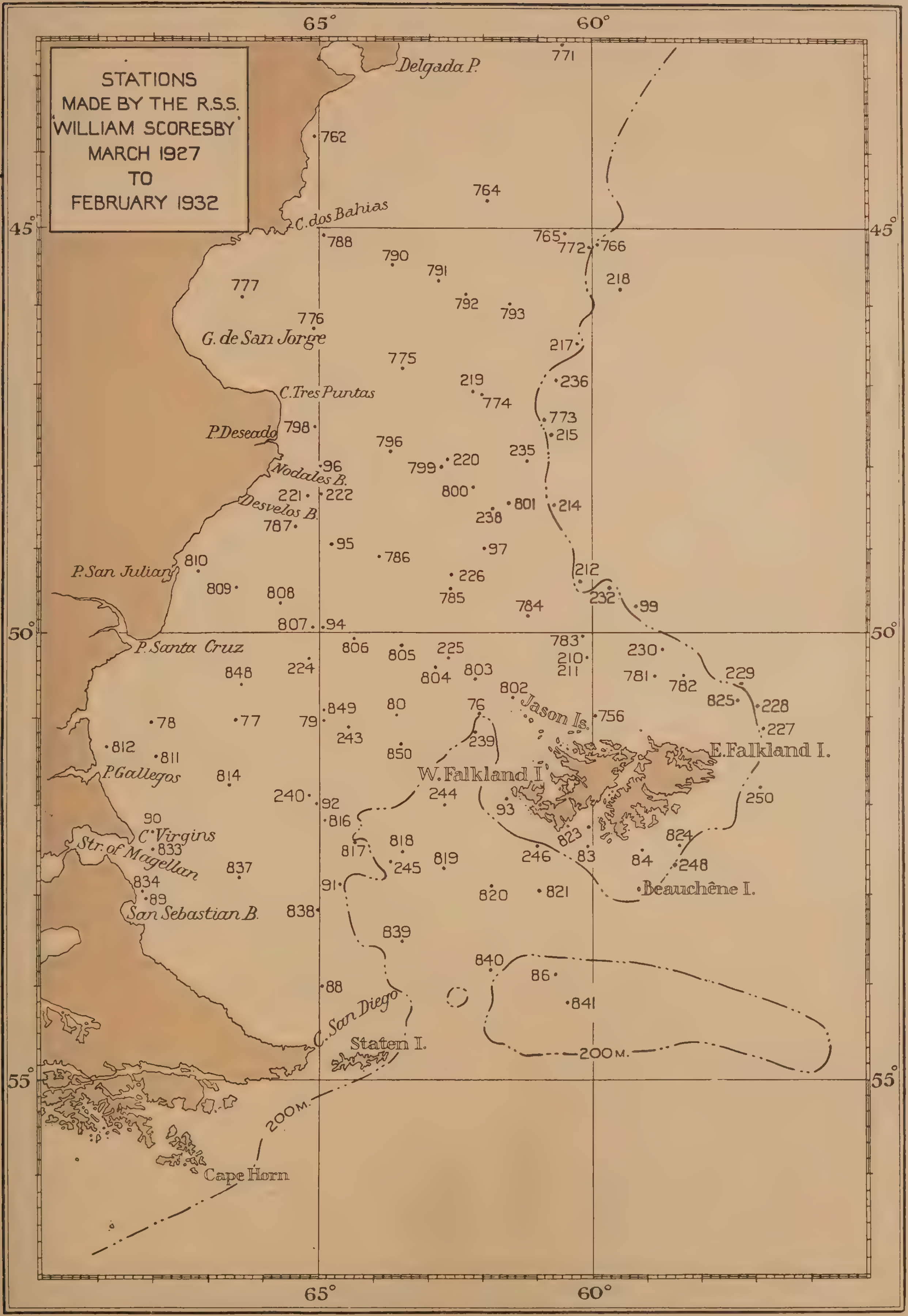
Tabulated data of the samples examined

Station	Date	Position		Depth (metres)	Texture (percentage of total)									Representative number	Ground texture	Type of deposit
		Lat. S	Long. W		I. Large fragments, 15 mm. and over	II. Very coarse gravel, 10–14 mm.	III. Coarse gravel, 5–9 mm.	IV. Medium gravel, 2·5–4·5 mm.	V. Fine gravel, 1·5–2·4 mm.	VI. Coarse sand, 1·0–1·4 mm.	VII. Medium sand, 0·5–0·9 mm.	VIII. Fine sand, 0·1–0·4 mm.	IX. Silt, under 0·1 mm.			
WS 76	11. iii. 27	51° 00′	62° 02′ 30″	207	—	—	—	+	+	+	6	74	19	0·12	VIII	F2
WS 77	12. iii. 27	51° 01′	66° 31′ 30″	110	—	—	—	+	1	3	39	60	1	0·31	VIII	D3
WS 78	13. iii. 27	51° 01′	68° 04′ 30″	95	—	—	—	—	—	+	4	93	2	0·12	VIII	D1
WS 79	13. iii. 27	51° 01′ 30″	64° 59′ 30″	132	—	—	+	2	2	2	8	84	1	0·26	VIII	D1
WS 80	14. iii. 27	50° 57′	63° 37′ 30″	152	—	—	+	2	1	1	16	73	6	0·28	VIII	D2
WS 83	24. iii. 27	14 miles S 64° W of George I., E. Falkland Is.		137	27	2	7	9	6	8	9	30	2	5·16	III	A3
WS 84	24. iii. 27	7½ miles S 9° W of Sea Lion Is., E. Falkland Is.		75	48	1	+	+	1	3	28	17	+	7·61	III	A4
WS 86	3. iv. 27	53° 53′ 30″	60° 34′ 30″	151	15	+	2	10	12	11	29	19	1	3·16	IV	A2
WS 88	6. iv. 27	54° 00′	64° 57′ 30″	118	22	4	15	15	2	2	6	34	1	4·83	IV	A5
WS 89	7. iv. 27	9 miles N 21° E of Arenas Lt., Tierra del Fuego		23	64	3	3	4	2	+	4	12	6	10·22	II	E3
WS 90	7. iv. 27	13 miles N 83° E of C. Virgins Lt., Argentina		82	—	—	+	4	2	2	13	76	3	0·30	VIII	E2
WS 91	8. iv. 27	52° 53′ 45″	64° 37′ 30″	191	44	1	1	1	1	2	15	36	+	6·84	III	D4
WS 92	8. iv. 27	51° 58′ 30″	65° 01′	145	—	2	8	7	4	4	18	58	1	1·04	VI	D4
WS 93	9. iv. 27	7 miles S 80° W of Beaver I., W. Falkland Is.		133	—	— —	—	2	6	9	36	45	2	0·44	VIII	A1
WS 94	16. iv. 27	50° 00′ 15″	64° 57′ 45″	110	—	2	1	—	+	+	7	90	2	0·16	VIII	C4
WS 95	17. iv. 27	48° 58′ 15″	64° 45′	109	15	—	2	7	7	2	3	62	1	2·99	IV	C5
WS 96	17. iv. 27	48° 00′ 15″	64° 58′	96	12	2	1	1	1	+	11	75	+	2·04	V	C3
WS 97	18. iv. 27	49° 00′ 30″	61° 58′	146	10	—	2	8	10	5	13	46	6	2·11	V	F4
WS 99	19. iv. 27	49° 42′	59° 14′ 30″	251	—		—	—	—	—	—	73	27	0·07	IX	F1
WS 210	29. v. 28	50° 17′	60° 06′	161	—	—	—	+	1	1	7	70	21	0·13	VIII	F2
WS 211	29. v. 28	50° 17′	60° 06′	161	—	—	—	—	+	1	7	83	9	0·13	VIII	F1
WS 212	30. v. 28	49° 22′	60° 10′	242	—	8	+	4	2	2	6	51	27	1·06	VI	F1
WS 214	31. v. 28	48° 25′	60° 40′	208	—	—	—	+	+	+	1	84	15	0·09	IX	F1
WS 215	31. v. 28	47° 37′	60° 50′	219	—	6	—	1	+	+	1	84	8	0·70	VIII	F3
WS 217	1. vi. 28	46° 28′	60° 18′	146	—	—	—	+	+	+	4	88	7	0·11	VIII	D1
WS 218	2. vi. 28	45° 45′	59° 35′	311	—	—	+	+	+	1	1	95	3	0·11	VIII	E2
WS 219	3. vi. 28	47° 06′	62° 12′	115	—	—	—	+	+	+	2	96	2	0·10	IX	C1
WS 220	3. vi. 28	47° 56′	62° 38′	108	—	—	—	—	+	+	2	97	1	0·11	VIII	C1
WS 221	4. vi. 28	48° 23′	65° 10′	76	58	8	6	4	3	3	5	10	2	10·04	II	C7
WS 222	8. vi. 28	48° 23′	65° 00′	100	+	+	+	1	1	2	15	81	+	0·28	VIII	C3
WS 224	9. vi. 28	50° 18′	65° 07′	124	—	—	1	4	5	4	14	65	7	0·38	VIII	D1
WS 225	9. vi. 28	50° 20′	62° 30′	162	60	1	1	2	1	1	5	27	1	9·24	III	D5

Station	Date	Position		Depth (metres)	Texture (percentage of total)									Representative number	Ground texture	Type of deposit
		Lat. S	Long. W		I. Large fragments, 15 mm. and over	II. Very coarse gravel, 10–14 mm.	III. Coarse gravel, 5–9 mm.	IV. Medium gravel, 2·5–4·5 mm.	V. Fine gravel, 1·5–2·4 mm.	VI. Coarse sand, 1·0–1·4 mm.	VII. Medium sand, 0·5–0·9 mm.	VIII. Fine sand, 0·1–0·4 mm.	IX. Silt, under 0·1 mm.			
WS 226	10. vi. 28	49° 20′	62° 30′	144	—	—	+	+	1	2	11	84	3	0·17	VIII	C4
WS 227	12. vi. 28	51° 08′	56° 50′	320	—	—	—	—	—	+	7	91	2	0·13	VIII	B2
WS 228	30. vi. 28	50° 50′	56° 58′	229	—	1	4	7	7	7	22	52	1	0·77	VII	A4
WS 229	1. vii. 28	50° 35′	57° 20′	210	—	—	—	+	+	+	1	97	2	0·11	VIII	B2
WS 230	3. vii. 28	50° 10′	58° 42′	169	—	—	—	+	+	1	9	57	33	0·12	VIII	B2
WS 232	5. vii. 28	49° 25′	59° 45′	198	—	—	—	2	2	1	5	71	18	0·17	VIII	F1
WS 235	6. vii. 28	47° 56′	61° 10′	155	—	—	—	—	+	+	4	93	3	0·11	VIII	C2
WS 236	6. vii. 28	46° 55′	60° 40′	272	—	—	—	—	—	—	1	82	17	0·08	IX	F1
WS 238	8. vii. 28	48° 30′	61° 50′	148	—	5	8	10	9	3	3	19	43	1·38	VI	E3
WS 239	15. vii. 28	51° 10′	62° 10′	196	—	—	—	1	+	1	14	59	25	0·16	VIII	F2
WS 240	16. vii. 28	51° 55′	65° 10′	144	—	—	1	3	4	9	37	45	+	0·48	VIII	C4
WS 242	17. vii. 28	51° 06′	66° 30′	119	—	—	+	1	+	1	6	91	2	0·16	VIII	D3
WS 243	17. vii. 28	51° 06′	64° 30′	144	—	—	—	2	3	3	10	78	4	0·23	VIII	D2
WS 244	18. vii. 28	52° 00′	62° 40′	253	—	—	+	1	1	1	4	88	5	0·16	VIII	F1
WS 245	18. vii. 28	52° 36′	63° 40′	304	51	+	3	2	2	1	4	34	3	7·89	III	E3
WS 246	19. vii. 28	52° 25′	61° 00′	192	28	2	1	2	2	4	14	43	3	4·70	IV	A3
WS 246	19. vii. 28	52° 25′	61° 00′	267	15	—	+	1	1	1	6	75	2	2·34	V	B4
WS 248	20. vii. 28	52° 40′	58° 30′	210	12	1	4	4	3	2	19	51	5	2·38	V	B3
WS 250	20. vii. 28	51° 45′	57° 00′	250	—	—	—	+	+	+	15	83	2	0·17	VIII	B4
WS 756	10. x. 31	50° 54′ 39″	59° 58′	118	—	—	—	8	7	3	9	63	12	0·40	VIII	F1
WS 762	16. x. 31	43° 50′ 30″	65° 01′ 51″	67	—	1	2	2	1	1	7	68	19	0·30	VIII	E3
WS 764	17. x. 31	44° 38′ 15″	61° 58′ 30″	106	—	—	—	+	+	+	2	88	10	0·10	IX	D1
WS 765	17. x. 31	45° 07′	60° 29′ 15″	113	—	—	—	+	+	+	1	89	10	0·09	IX	C2
WS 766	18. x. 31	45° 13′	59° 56′ 30″	545	7	1	2	2	1	1	1	81	6	1·37	VI	E3
WS 771	29. x. 31	42° 41′ 45″	60° 31′	90	—	—	+	+	+	+	3	91	5	0·10	IX	C2
WS 772	30. x. 31	45° 13′ 22″	60° 00′ 15″	309	—	—	—	—	—	—	1	98	1	0·10	IX	C3
WS 773	31. x. 31	47° 20′	60° 51′	291	—	—	—	—	—	—	+	17	83	0·02	IX	F1
WS 774	1. xi. 31	47° 08′	62° 02′	139	—	—	—	+	+	+	3	86	10	0·11	VIII	C2
WS 775	2. xi. 31	46° 44′ 45″	63° 33′	115	—	—	—	+	+	+	+	94	5	0·10	IX	F2
WS 776	3. xi. 31	46° 18′ 15″	65° 02′ 15″	110	—	—	—	—	—	—	+	56	43	0·06	IX	E1
WS 777	3. xi. 31	45° 56′	66° 24′	98	—	—	—	—	—	—	—	6	94	0·01	IX	E1
WS 781	6. xi. 31	50° 30′	58° 50′	148	—	—	—	+	+	+	2	88	10	0·10	IX	B2
WS 782	4. xii. 31	50° 29′ 15″	58° 23′ 45″	141	—	—	—	—	—	—	2	94	5	0·10	IX	B2
WS 783	5. xii. 31	50° 02′ 45″	60° 10′	155	1	1	1	2	1	1	3	75	16	0·35	VIII	F2
WS 784	5. xii. 31	49° 47′ 45″	61° 05′	170	—	—	2	+	1	1	4	79	14	0·21	VIII	F2
WS 785	6. xii. 31	49° 26′ 30″	62° 34′	150	—	—	+	+	+	+	2	95	2	0·14	VIII	D1
WS 786	7. xii. 31	49° 07′	63° 55′	133	—	—	—	+	+	+	2	96	2	0·10	VIII	D1
WS 787	7. xii. 31	48° 44′ 01″	65° 24′ 30″	106	32	3	1	1	2	1	2	57	1	5·32	III	C1
WS 788	13. xii. 31	45° 07′	65° 54′	82	—	—	1	2	1	1	5	47	45	0·16	VIII	E3
WS 790	14. xii. 31	45° 28′ 52″	63° 40′ 37″	92	—	—	—	+	+	+	2	65	32	0·09	IX	F1

Station	Date	Position		Depth (metres)	Texture (percentage of total)									Repre-sentative number	Ground texture	Type of deposit
		Lat. S	Long. W		I. Large fragments, 15 mm. and over	II. Very coarse gravel, 10–14 mm.	III. Coarse gravel, 5–9 mm.	IV. Medium gravel, 2·5–4·5 mm.	V. Fine gravel, 1·5–2·4 mm.	VI. Coarse sand, 1·0–1·4 mm.	VII. Medium sand, 0·5–0·9 mm.	VIII. Fine sand, 0·1–0·4 mm.	IX. Silt, under 0·1 mm.			
WS 791	14. xii. 31	45° 38′ 45″	62° 55′	97	—	—	+	+	+	+	2	85	13	0·10	IX	F1
WS 792	15. xii. 31	45° 49′ 30″	62° 20′ 15″	102	—	—	—	+	+	+	2	92	6	0·10	IX	C2
WS 793	15. xii. 31	45° 58′	61° 42′	110	—	—	—	—	—	—	1	92	8	0·10	IX	D1
WS 796	19. xii. 31	47° 59′ 37″	63° 42′ 30″	106	—	—	—	—	—	—	2	98	+	0·11	VIII	C1
WS 798	20. xii. 31	47° 32′	65° 02′	49	5	9	41	20	5	2	3	14	1	4·36	IV	D5
WS 799	21. xii. 31	48° 04′ 15″	62° 48′ 07″	141	—	+	4	8	10	3	6	56	13	0·70	VII	C5
WS 800	21. xii. 31	48° 15′ 45″	62° 09′ 52″	139	8	—	2	7	7	4	9	62	1	1·76	V	D4
WS 801	22. xii. 31	48° 26′ 15″	61° 28′	165	—	—	+	+	+	+	+	96	3	0·12	VIII	C2
WS 802	3. i. 32	50° 46′	61° 20′	137	—	—	—	1	5	6	18	67	3	0·32	VIII	A1
WS 803	5. i. 32	50° 33′ 45″	62° 05′ 30″	174	54	11	5	4	2	1	9	14	1	9·69	III	D5
WS 804	6. i. 32	50° 22′ 45″	62° 49′	150	16	6	5	6	4	6	25	31	1	3·67	III	C6
WS 805	6. i. 32	50° 10′ 15″	63° 29′	148	29	13	5	14	5	3	10	20	2	6·30	III	D5
WS 806	7. i. 32	50° 03′ 30″	64° 21′	130	—	1	+	+	+	+	4	93	1	0·19	VIII	C4
WS 807	7. i. 32	41° 50′ 30″	65° 03′	125	6	2	3	9	5	3	8	61	2	1·74	V	C5
WS 808	8. i. 32	49° 40′ 25″	65° 42′	110	1	—	—	+	+	1	2	96	+	0·12	VIII	C1
WS 809	8. i. 32	49° 28′ 15″	66° 29′	107	—	—	—	+	+	1	5	94	1	0·13	VIII	C1
WS 810	9. i. 32	49° 17′	67° 08′	95	—	—	—	—	—	—	—	94	6	0·09	IX	F2
WS 811	10. i. 32	51° 27′ 45″	68° 01′ 30″	98	20	1	5	10	9	7	15	35	2	4·22	IV	D3
WS 812	10. i. 32	51° 16′ 15″	68° 52′	53	—	—	—	—	—	—	—	11	89	0·01	IX	E1
WS 814	13. i. 32	51° 45′ 15″	66° 40′	111	—	—	+	1	1	1	18	79	1	0·23	VIII	D3
WS 816	14. i. 32	52° 09′ 45″	64° 56′	150	44	3	18	17	6	2	2	8	+	8·37	III	D5
WS 817	14. i. 32	52° 23′	64° 19′	191	—	—	—	+	+	+	13	86	+	0·16	VIII	D3
WS 818	17. i. 32	52° 31′ 15″	63° 25′	272	35	13	9	4	2	1	4	32	1	7·21	III	F3
WS 819	17. i. 32	52° 41′ 52″	62° 39′ 30″	312	—	—	—	+	1	1	4	87	7	0·13	VIII	F2
WS 820	18. i. 32	52° 53′ 15″	61° 51′ 30″	351	—	+	+	+	+	+	1	85	13	0·11	VIII	F2
WS 821	19. i. 32	52° 55′ 45″	60° 55′	461	—	—	—	1	+	+	1	74	23	0·11	VIII	F1
WS 823	19. i. 32	52° 14′ 30″	60° 01′	80	—	—	—	—	+	+	3	94	4	0·11	VIII	B1
WS 824	19. i. 32	52° 29′ 15″	58° 27′ 15″	146	—	—	+	+	1	2	12	81	3	0·20	VIII	B2
WS 825	28. i. 32	50° 50′	57° 15′ 15″	135	35	6	6	7	5	5	12	24	+	6·54	III	A4
WS 833	1. ii. 32	52° 30′	68° 00′	38	—	—	—	+	+	1	6	78	14	0·13	VIII	E3
WS 834	2. ii. 32	52° 57′ 45″	68° 08′ 15″	27	69	9	5	3	2	2	3	4	3	11·74	II	E3
WS 837	3. ii. 32	52° 49′ 15″	66° 28′	98	—	—	4	11	8	12	26	37	1	1·10	VI	C5
WS 838	5. ii. 32	53° 11′ 45″	65° 00′	148	—	—	+	2	1	+	9	87	1	0·21	VIII	C6
WS 839	5. ii. 32	53° 30′ 15″	63° 29′	403	—	—	—	—	—	+	+	81	19	0·08	IX	F1
WS 840	6. ii. 32	53° 52′ 30″	61° 49′ 15″	368	—	—	—	—	+	+	4	93	2	0·12	VIII	E2
WS 841	6. ii. 32	54° 11′ 45″	60° 21′ 30″	109	55	4	19	16	4	1	1	1	1	10·03	II	E4
WS 848	10. ii. 32	50° 37′ 30″	66° 24′	115	46	1	5	8	4	2	10	22	1	7·63	III	D4
WS 849	10. ii. 32	50° 52′ 45″	64° 58′	137	9	1	1	3	2	2	8	71	2	1·71	V	D2
WS 850	11. ii. 32	51° 18′ 45″	63° 30′ 15″	157	6	8	15	24	8	3	8	28	1	3·33	IV	D5



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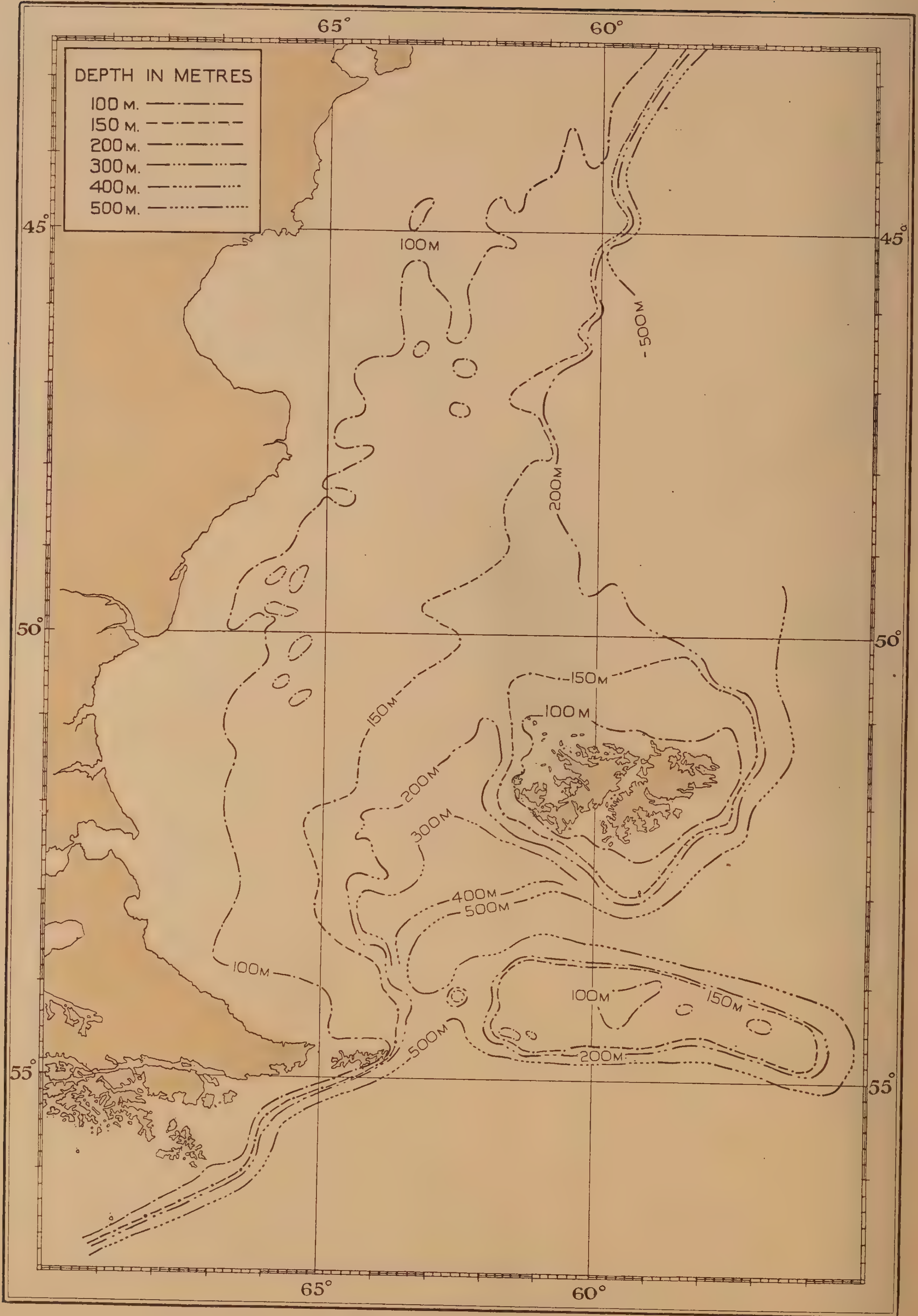
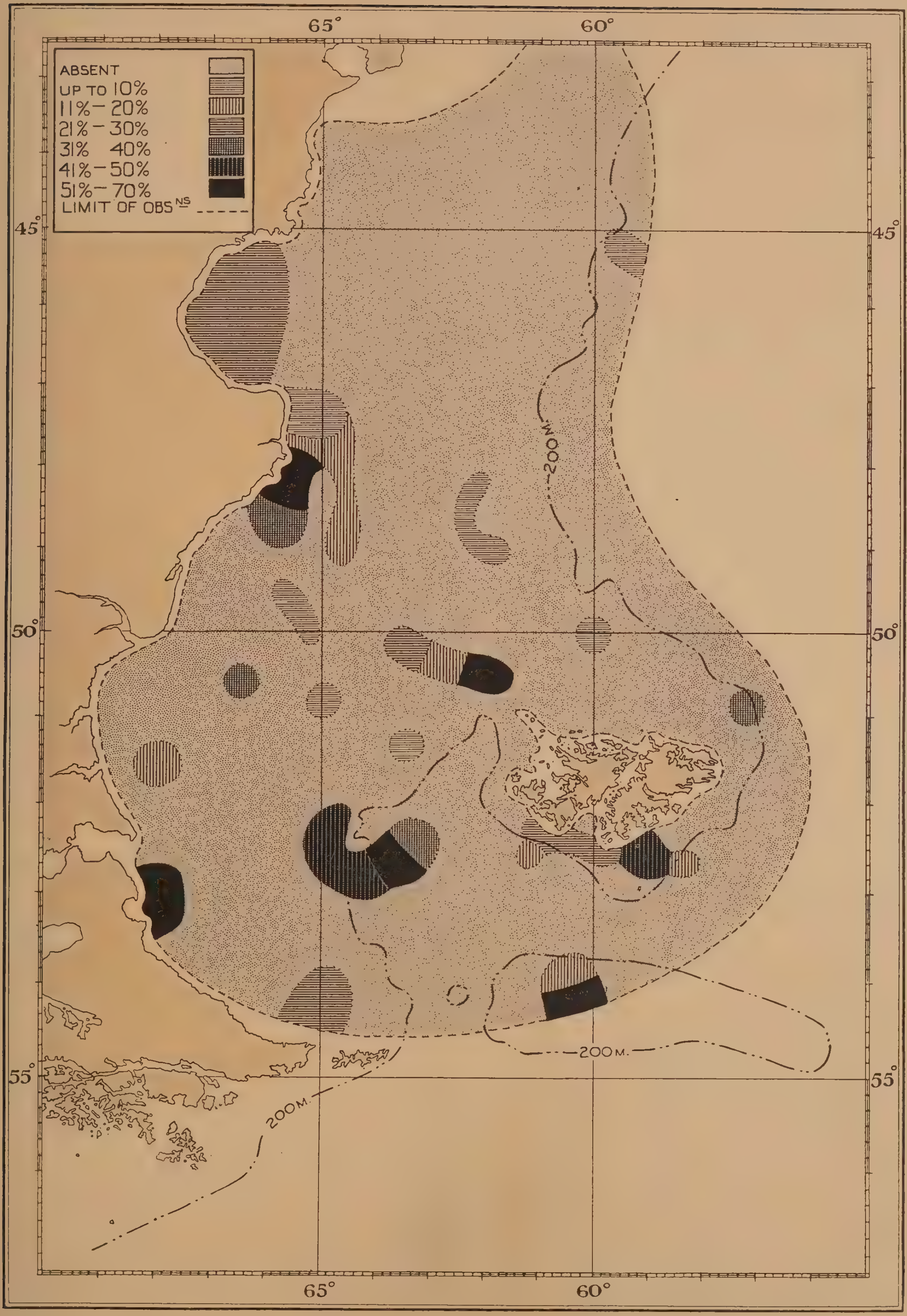


TOPOGRAPHY OF THE SEA BOTTOM



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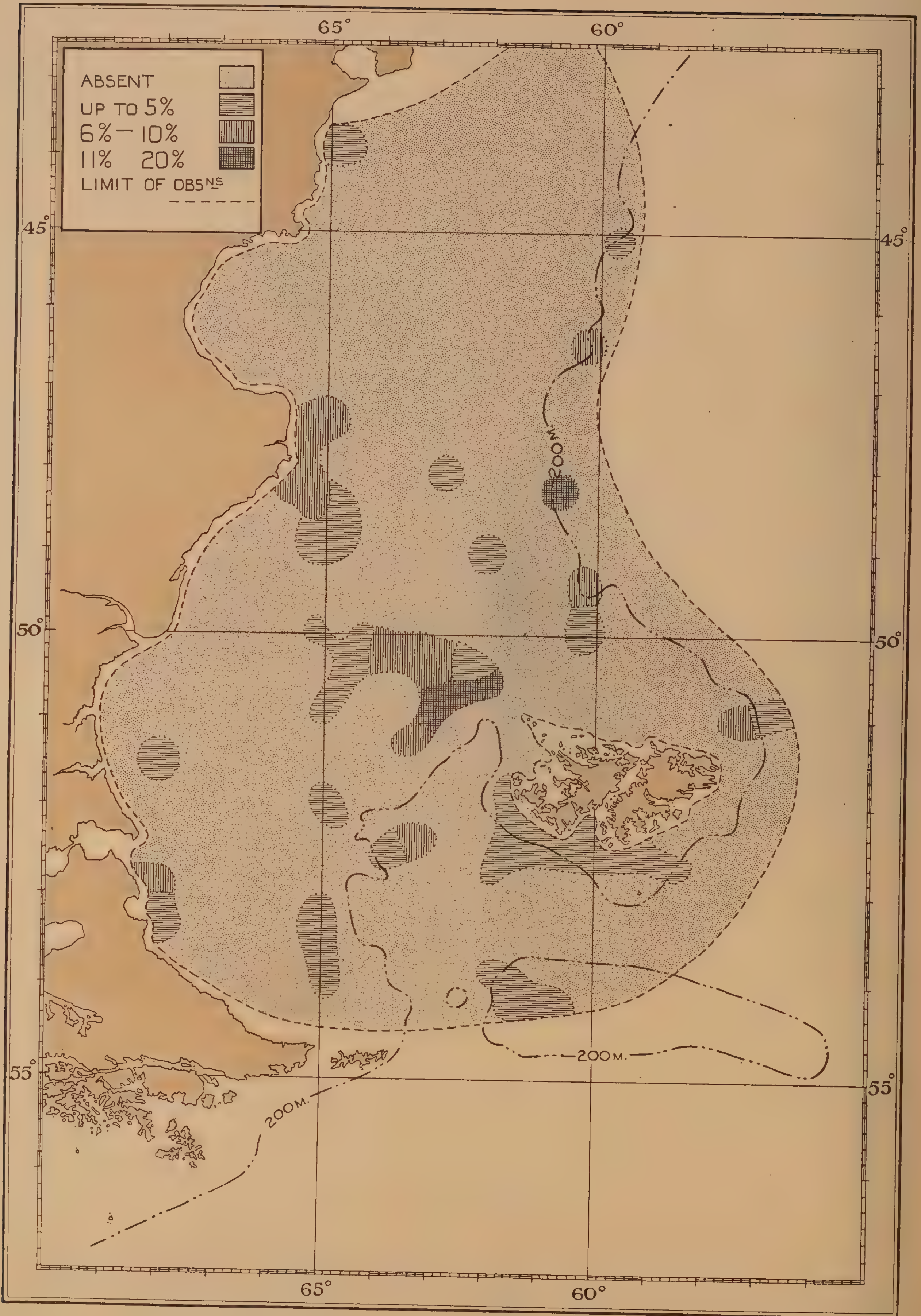

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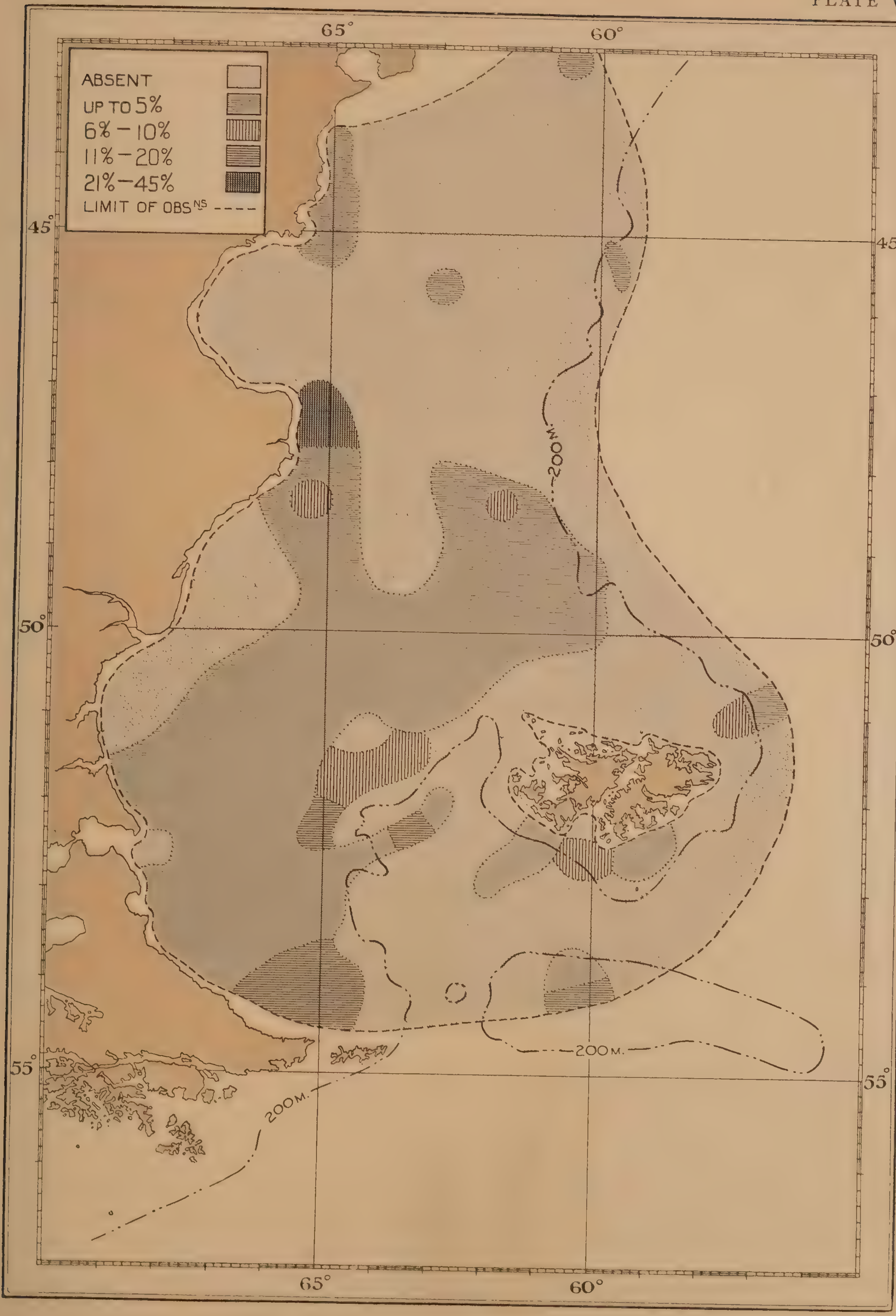

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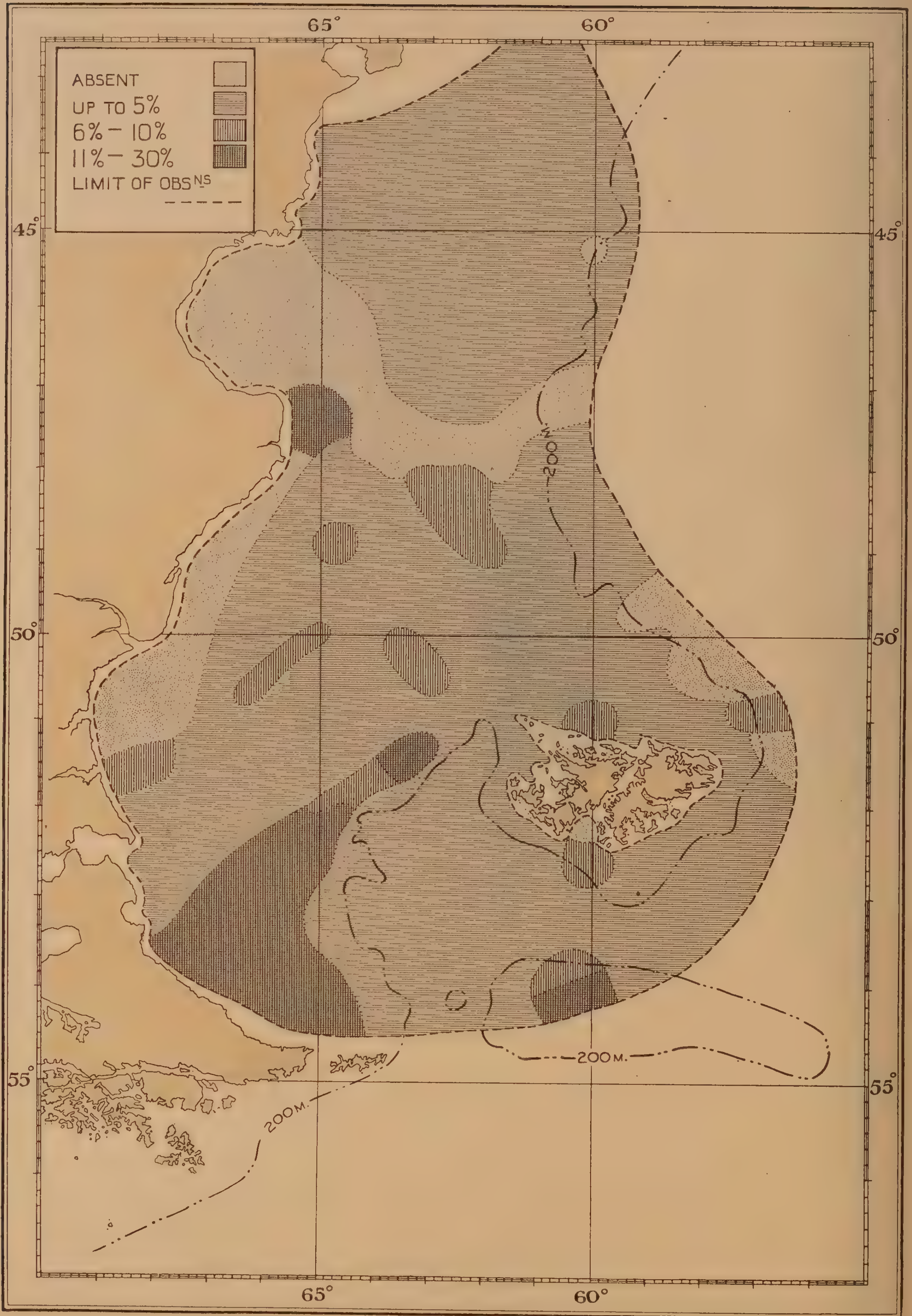

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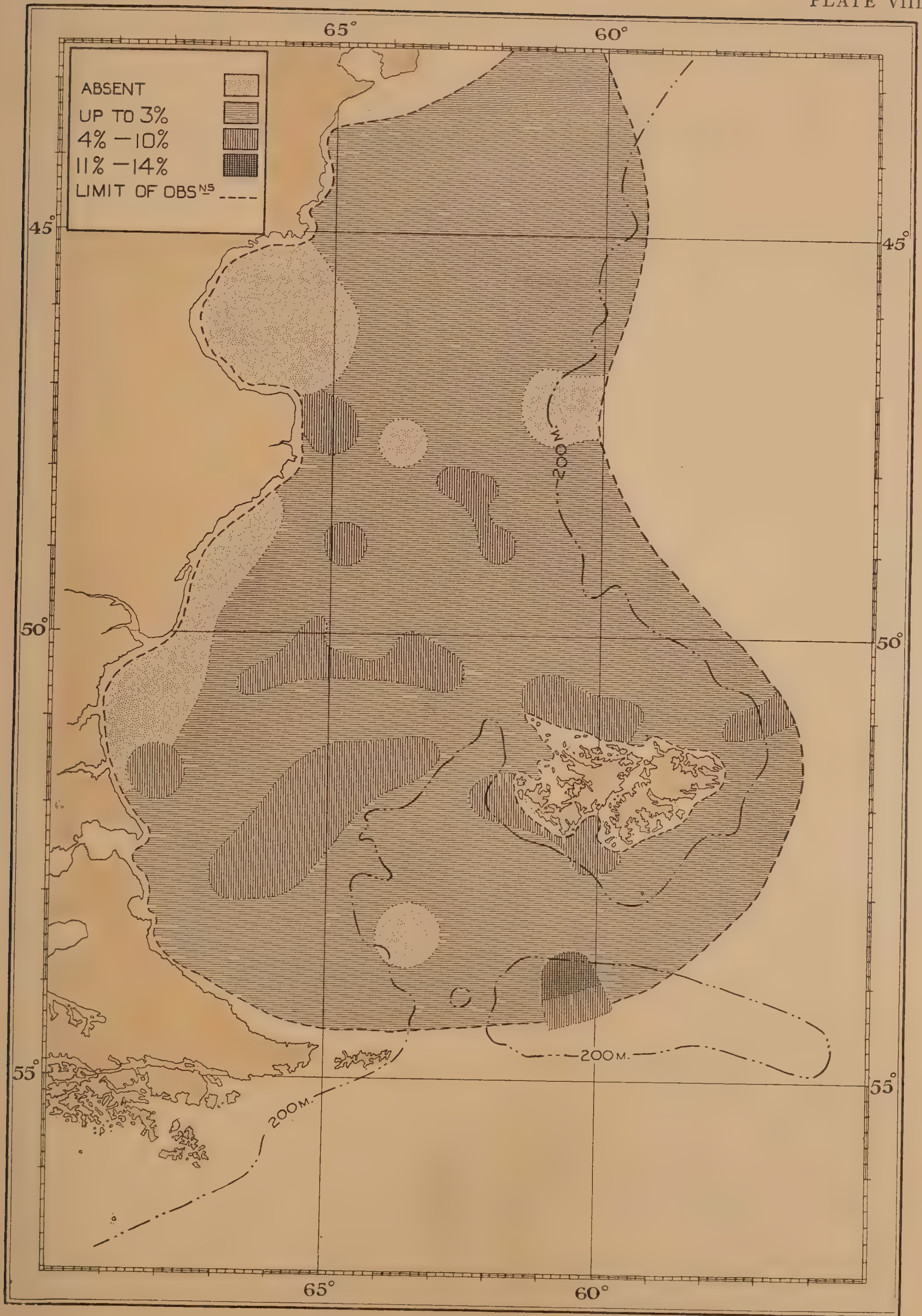

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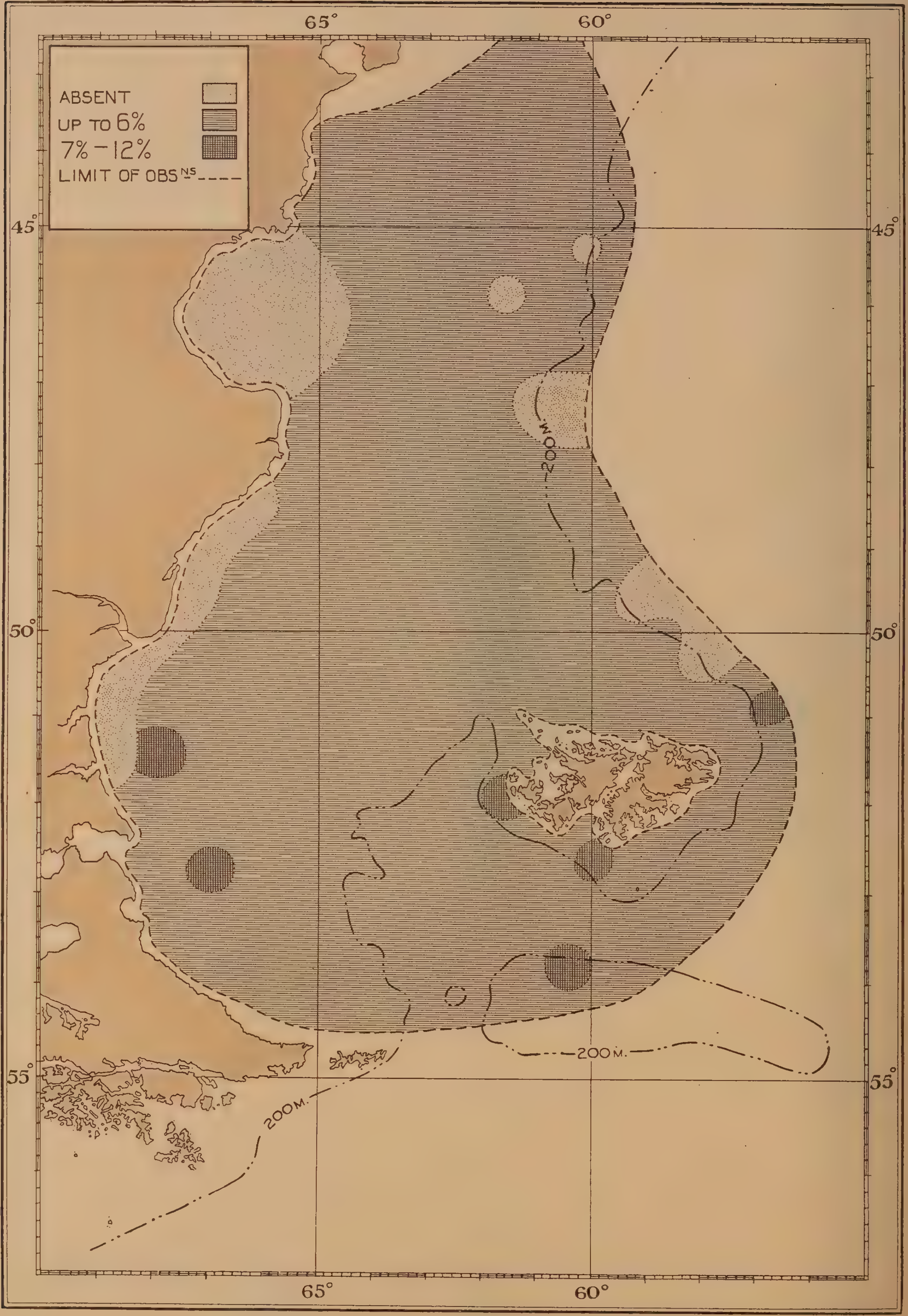

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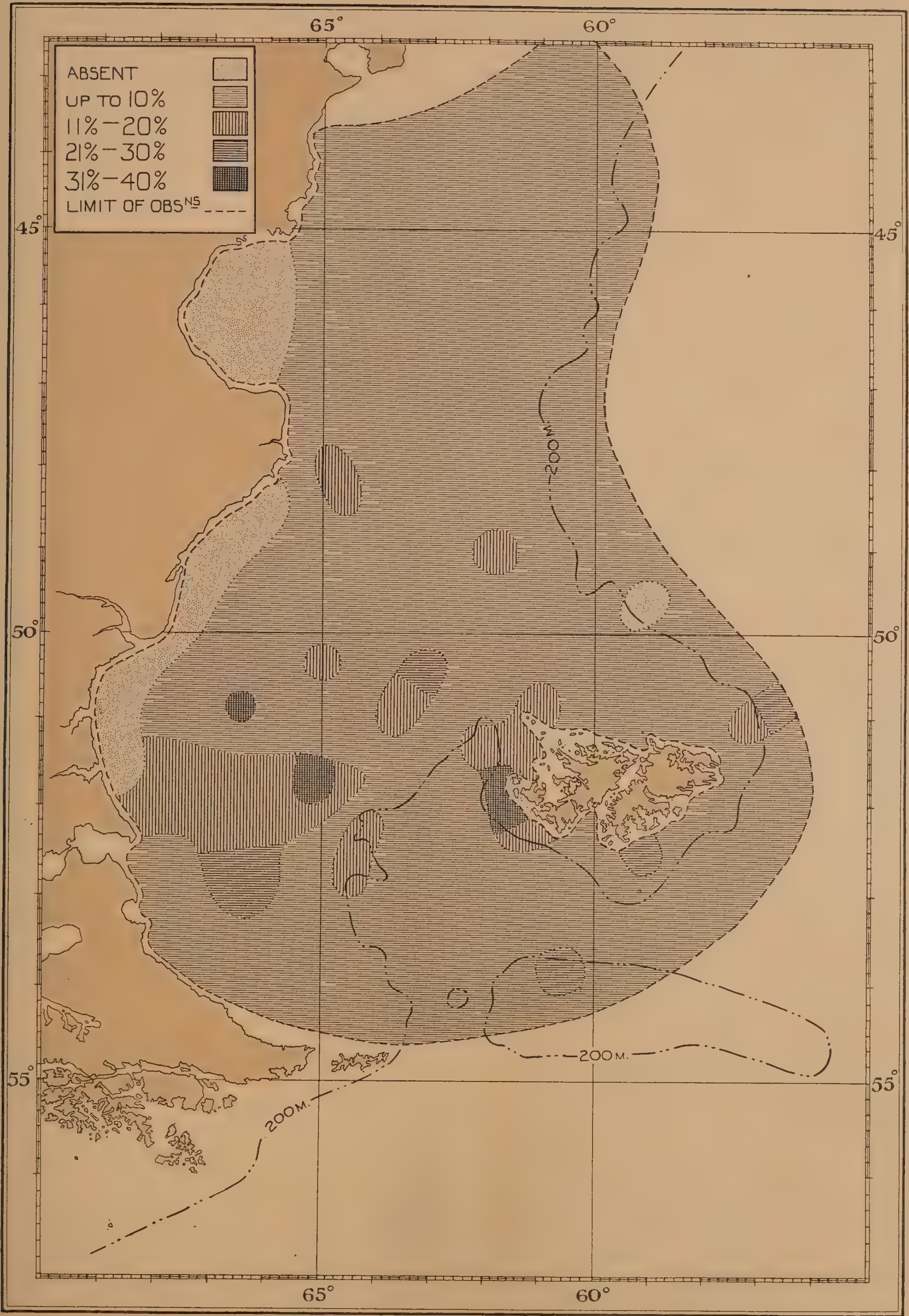

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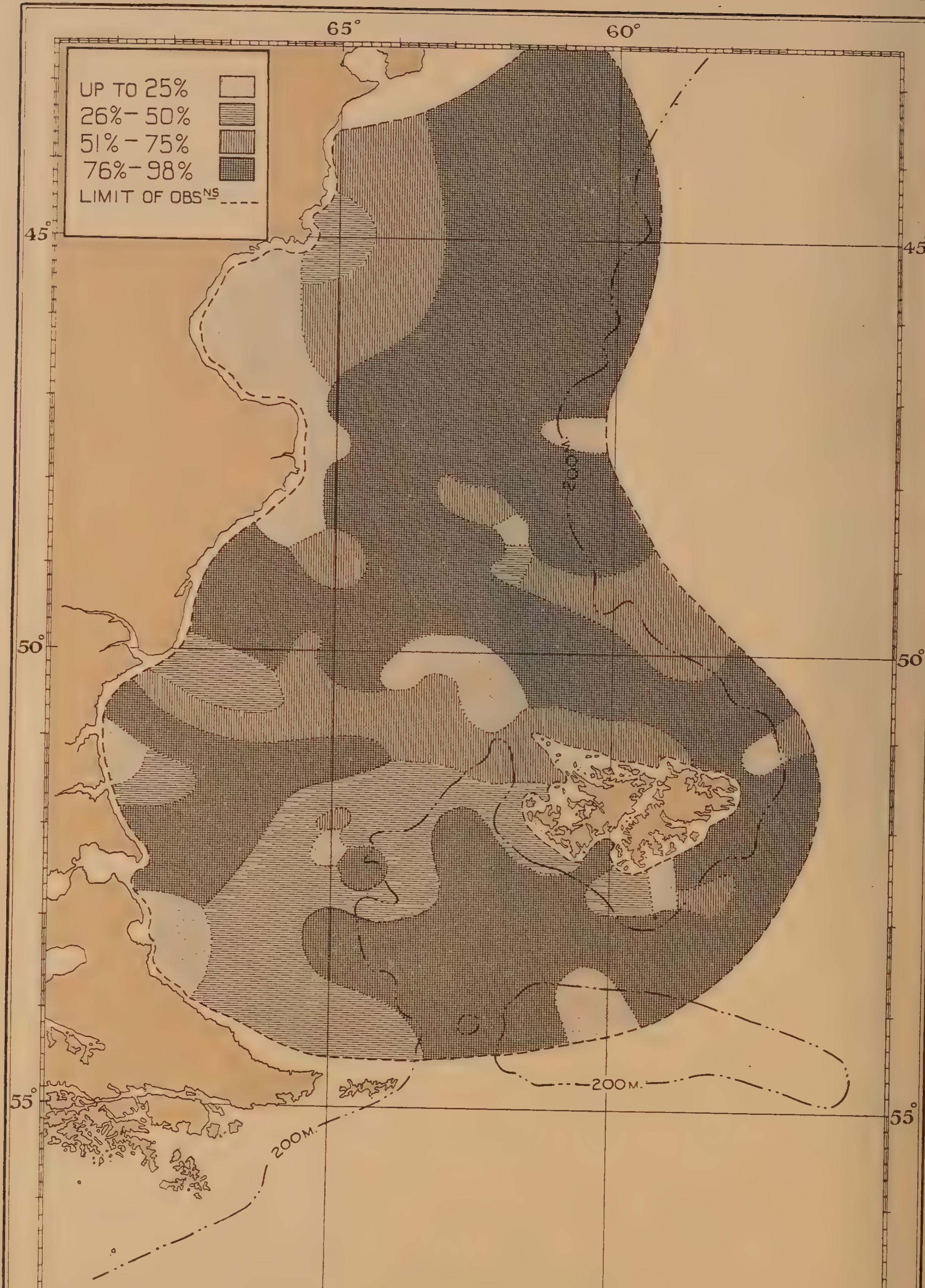

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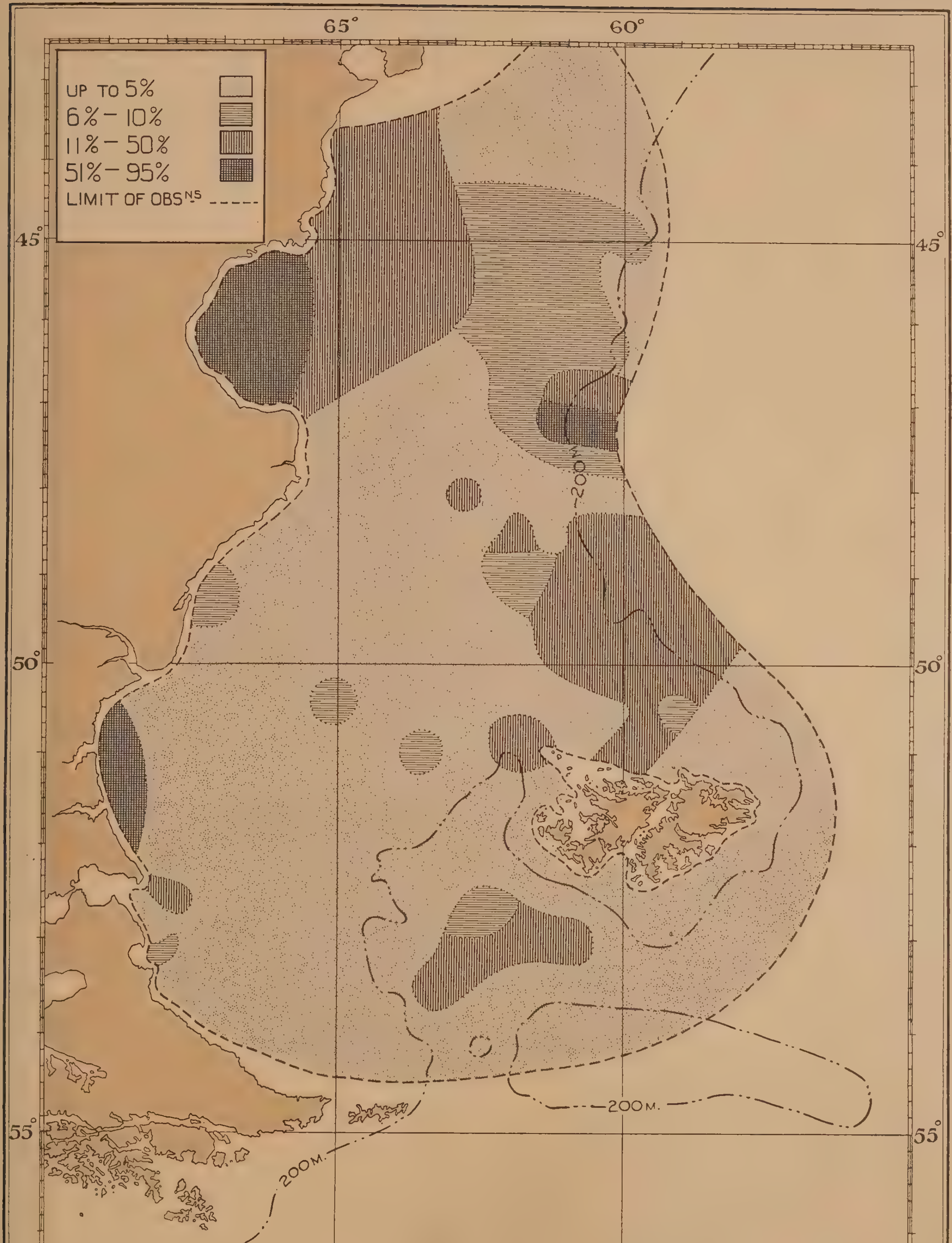

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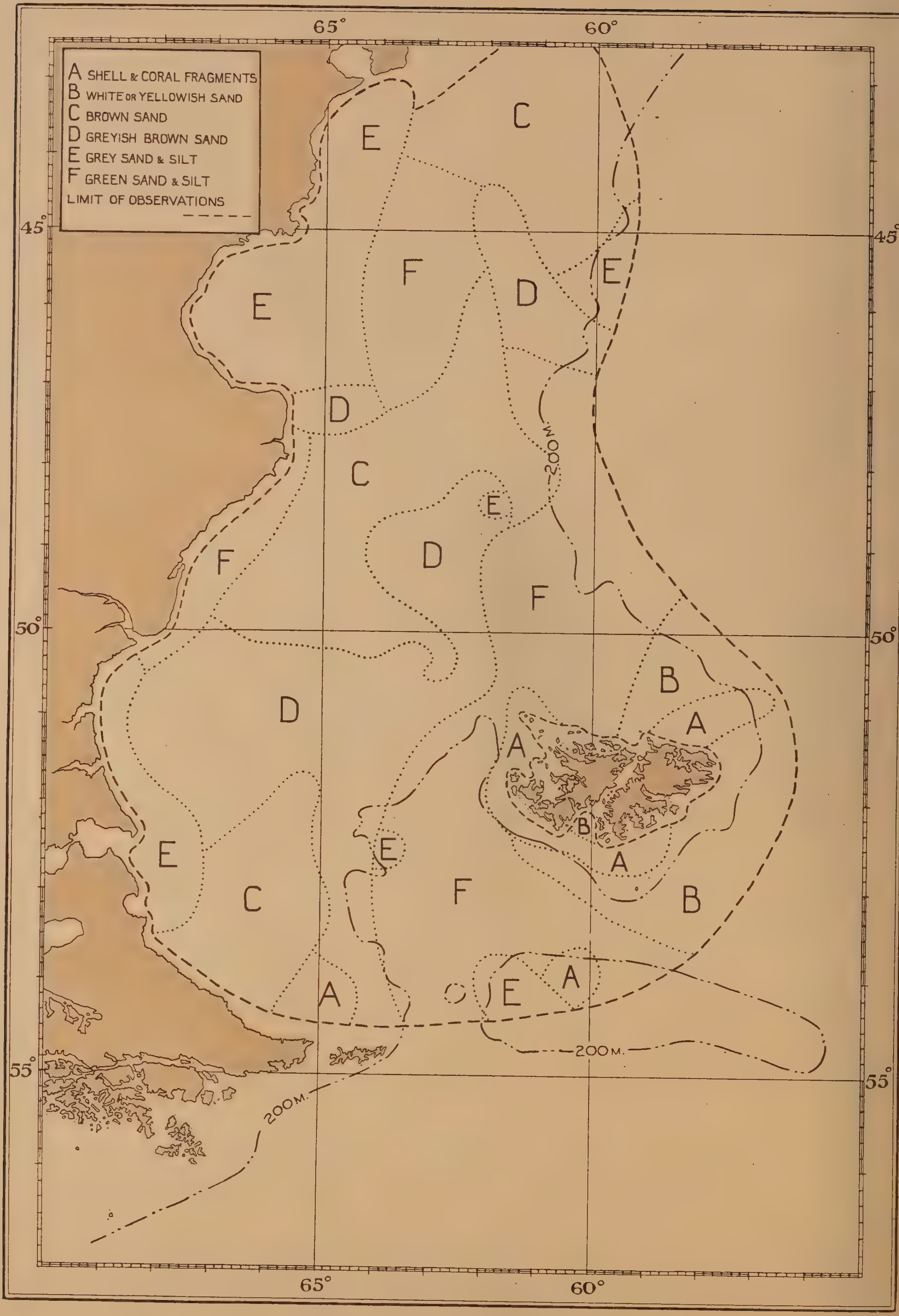

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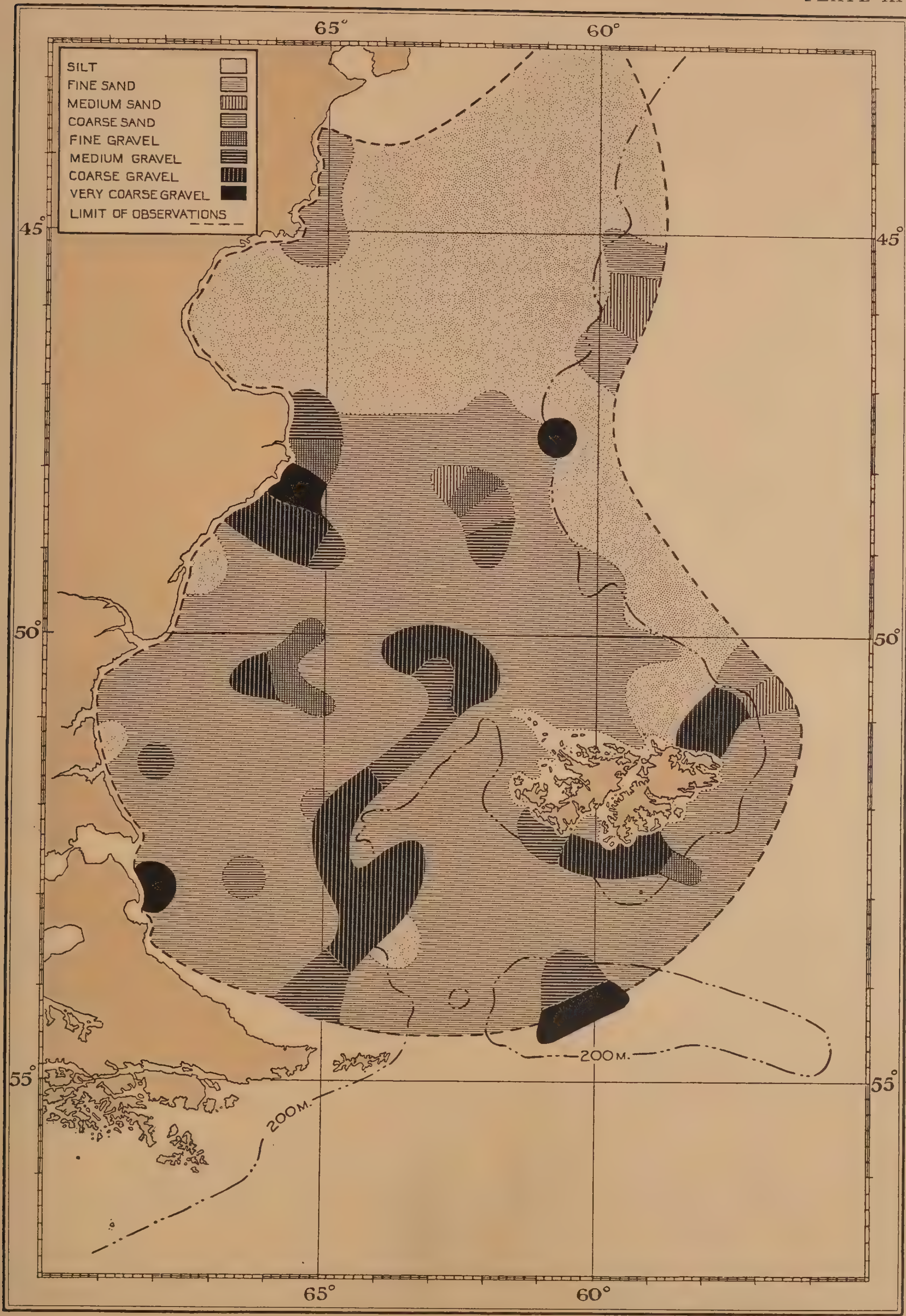

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[*Discovery Reports. Vol. IX, pp.* 207–214, *September*, 1934]

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INVESTIGATIONS

THE DEVELOPMENT OF *RHINCALANUS*

By

ROBERT GURNEY

THE DEVELOPMENT OF *RHINCALANUS*

By Robert Gurney

(Text-figs. 1–7)

The study of the development of the marine Calanoida presents peculiar difficulties, inasmuch as very few species carry their eggs, and it is consequently rarely possible to identify the nauplius by hatching from the egg. This has only been done in the case of *Calanus finmarchicus* (Lebour, 1916; Gibbons, 1933).[1] In other cases the series of stages has been laboriously traced out by examination of plankton material, and it is therefore not surprising that, of all the marine Calanoids, we know only the development of the following:

CALANIDAE. *Calanus finmarchicus.*

PARACALANIDAE. *Paracalanus parvus* (Oberg, 1905).

PSEUDOCALANIDAE. *Pseudocalanus elongatus* (Oberg).

CENTROPAGIDAE. *Centropages hamatus* (Oberg); *C. kroyeri* (Grandori, 1912); *C. typicus* (Grandori, 1925).

TEMORIDAE. *Temora longicornis* (Oberg).

ACARTIIDAE. *Acartia bifilosa*, *A. clausi* (Oberg); *A. clausi* (Grandori, 1912).

There are, it is true, partial descriptions, particularly of copepodid stages, of a number of other forms, but of complete life histories no more are known. I feel, therefore, that no apology is needed for offering a description of the larval stages of *Rhincalanus*, a genus of the Eucalanidae.

The material was derived mainly from a plankton sample taken by the R.R.S. 'Discovery' at St. 278, off Port Gentil, French Congo, on August 8, 1927. This sample contained numerous nauplii and early copepodid stages of *R. cornutus*, but no adults or copepodids older than stage IV. The later stages have been obtained from other samples taken off the African coast, but in none of them have nauplii or early copepodids been found. The nauplii of *R. cornutus* are all in the last three stages, but a few nauplii of *R. nasutus* were found in material from St. 93, off Saldanha Bay, south-west Africa, which represent five of the probable six stages. These two series can conveniently be taken together, as the differences between them are very small.

The nauplius of *R. nasutus* was identified by Giesbrecht (1893) by observation of the moult to the copepodid stage, and he made use of this elongated nauplius to disprove Claus' statement, which had gained general acceptance, that maxilla and maxillipede of Copepoda are parts of one appendage. It is curious that Claus, who in 1866 had figured an elongated nauplius of the same general form as that of *Rhincalanus*, did not himself

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[1] Since this was written, Mr A. G. Nicholls (1934) has published an account of the development of *Euchaeta norvegica* from the egg.

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Pseudocalanidae. *Pseudocalanus elongatus* (Oberg).

Centropagidae. *Centropages hamatus* (Oberg); *C. kroyeri* (Grandori, 1912); *C. typicus* (Grandori, 1925).

Temoridae. *Temora longicornis* (Oberg).

Acartiidae. *Acartia bifilosa*, *A. clausi* (Oberg); *A. clausi* (Grandori, 1912).

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With (1915, p. 46) has described copepodid IV and V of *R. nasutus*, and has figured leg 5 of the male in these two stages. Schmaus and Lehnhofer (1927) have dealt with the later copepodid stages of all three species of *Rhincalanus* and particularly with the development of leg 5 of the male. They showed also that there are two forms of *R. cornutus* (forma *typica* and forma *atlantica*) distinguished by the form of leg 5, and that similar differences can be seen in copepodid stages IV and V.

THE NAUPLIUS STAGES

Five stages only are recognizable in the material, but it is almost certain that the youngest is actually stage II.

Stage II, *R. cornutus*. Length 0·45–0·47 mm. (Fig. 1.)

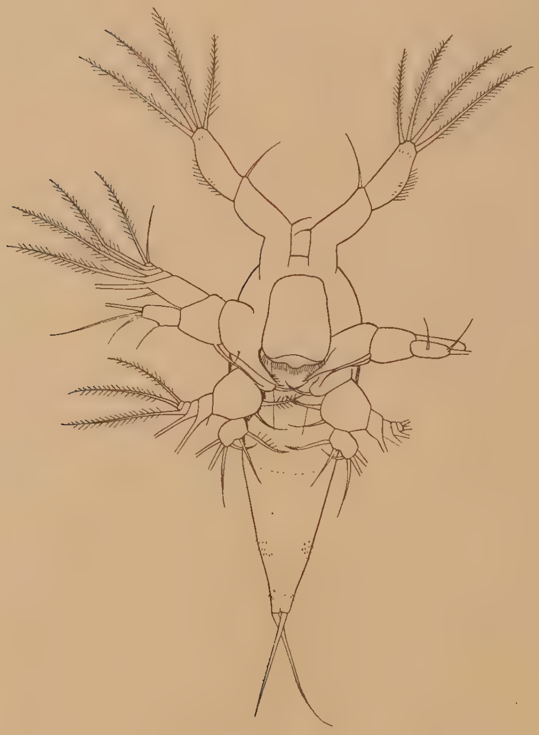

Fig. 1.

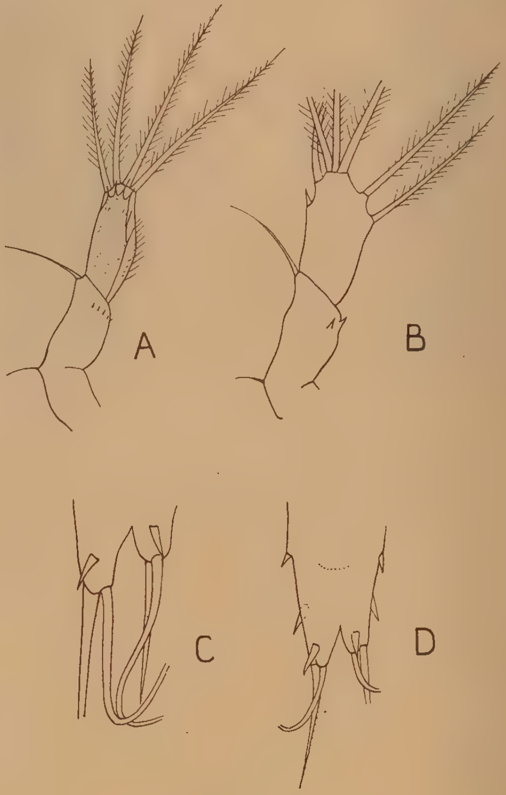

Fig. 2.

Rhincalanus nasutus, nauplius stages.

Fig. 1. Stage II. Fig. 2. A, antennule, stage II; B, antennule, stage III; C, furcal region, stage III; D, furcal region, stage IV.

Body pear-shaped, tapering gradually backwards, with a dorsal line of segmentation in the maxillary region. Furcal region with one pair of unequal setae, that of the right side being the longer, and crossing dorsally over the left one. Labrum very large, more or less rectangular, and fringed with fine hairs.

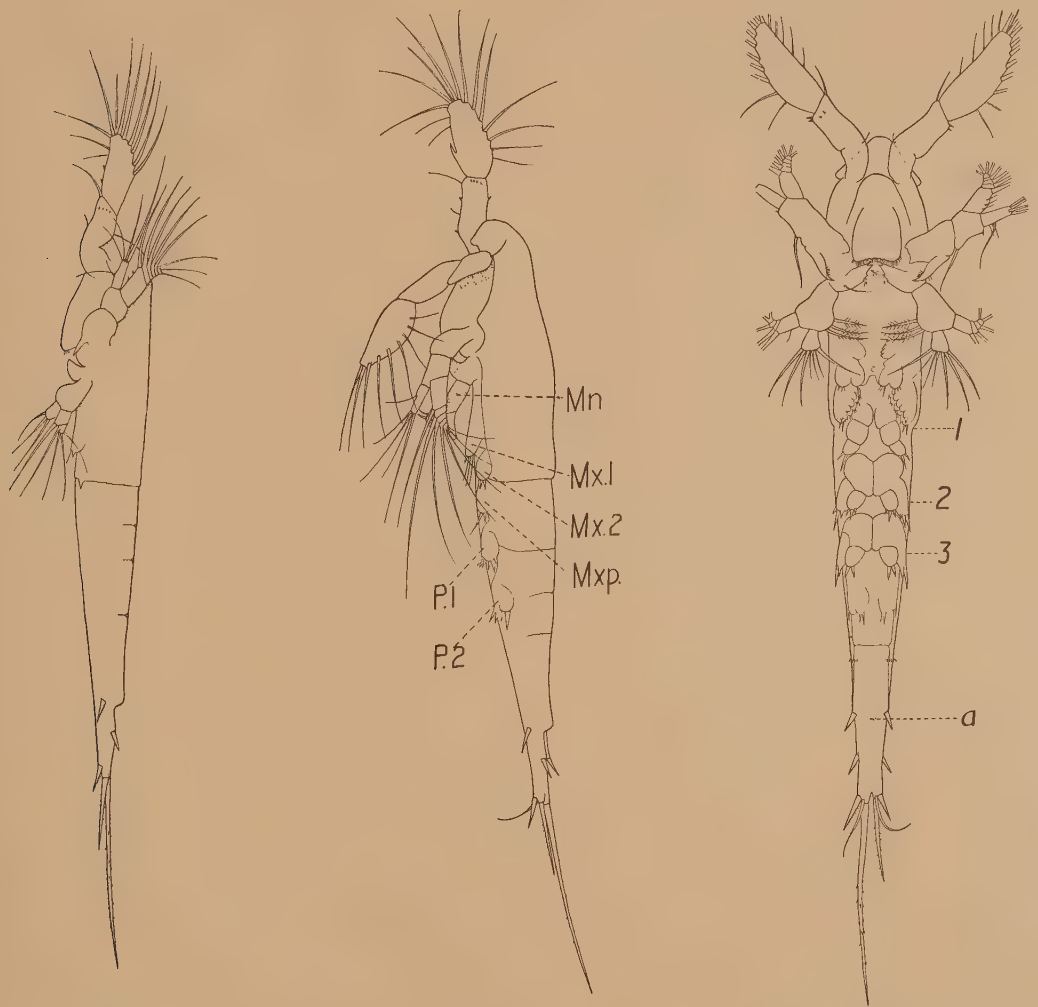

Fig. 3. Fig. 4. Fig. 5.

Rhincalanus cornutus, nauplius stages.

Fig. 3. Stage V, lateral view. Fig. 4. Stage VI, lateral view. Fig. 5. Stage VI, ventral view. 1, 2, 3 indicate lines of division between somites dorsally. *a*, position of anus.

Antennules (Fig. 2 A) with four apical setae, without aesthete; segments 1 and 2 not clearly jointed, each with a small seta at end. The seta of segment 1 is very small, and neither at this, nor in any later stage, has a proximal seta been seen on segment 2, although two setae on this segment is the rule among Copepoda.

Antenna with large molar process on coxa; exopod with seven setae.

Mandible segment 1 with a strong spine, but without molar process; exopod with five setae; endopod an undivided plate, with six setae or spines.

Stage III, *R. cornutus*. Length 0·65–0·70, average 0·66 mm.

Body more elongated, the length about $3\frac{1}{2}$ times greatest width. Furcal region (Fig. 2 C) cleft, each branch bearing a short spine on ventral surface, a terminal spine, and an inner terminal soft seta. The right spine is longer than the left, but only about one-tenth length of body.

Antennule with six terminal setae, but no aesthete. (Fig. 2 B.)

Antenna, exopod with eight setae.

There is no trace of the maxillule.

Stage IV. Length: *R. nasutus*, 0·82–0·89, average 0·85 mm.; *R. cornutus*, 1·0 mm.

Body now very slender, five times as long as wide. Furcal region with two additional pairs of lateral spines. In *R. nasutus* the furcal spines have scarcely increased in length, so that the right spine is now shorter in proportion to the body, and not greatly longer than the left one (62 : 49). In *R. cornutus* it is nearly one-third of the length of the body (60 : 195) and about $2\frac{1}{2}$ times as long as the left spine (57 : 22).

Mandible with strong molar process on coxa.

Antennule with eight setae and aesthete, arranged thus: 5–A–3.[1] In some specimens of *R. cornutus* the maxillule is represented by a slight fold with a small projecting spinule, but I have seen no trace of it in *R. nasutus*.

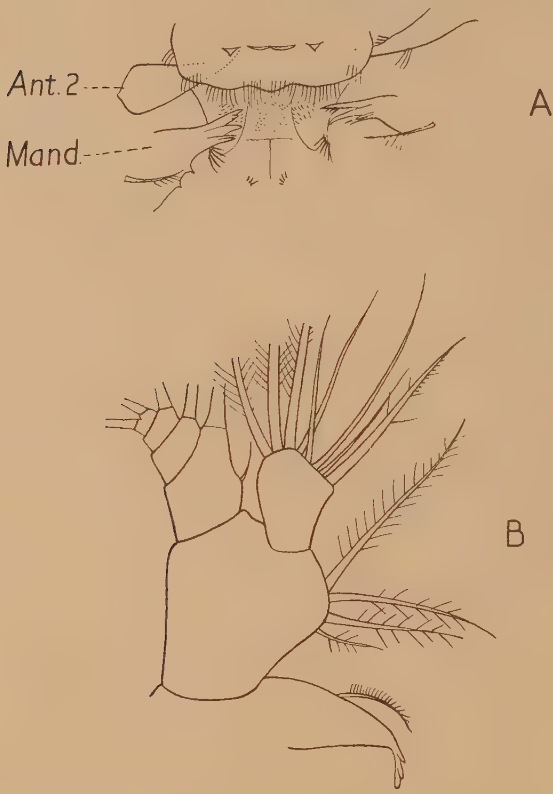

Fig. 6. *Rhincalanus cornutus*. Nauplius, stages V and VI. A, upper lip, stage VI, showing arrangement of hairs on body wall; B, mandible, stage V.

Stage V. Length: *R. nasutus*, 1 mm.; *R. cornutus*, 1·2 mm.

Antennule with 7–A–4 terminal setae.

Maxillule distinct, as a small fold bearing a small seta.

Maxilla traceable as a faint fold with a minute spine.

Body distinctly divided into an anterior region including the somite of the maxilla, and a posterior region in which three additional somites can be seen under the skin just before the moult.

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[1] The arrangement of the setae on segment 3 may be conveniently expressed in this way: the first number being the setae behind the aesthete (A), and the second those in front of it.

Stage VI. Length: *R. nasutus*, 1·16 mm.; *R. cornutus*, 1·33 mm.

I have seen only one specimen of *R. nasutus* at this stage, which is probably below the average length.

Antennule with setae 9–A–6.

Maxillule and maxilla projecting as small lobes, the former with a few slender setae, and the latter with two small spines. Maxillipede represented by a small fold bearing a spine and a seta, and borne upon the same somite as the rudiment of leg 1. Legs 1 and 2 both represented by bilobed rudiments bearing small spines. The general form of the copepodid appendages can generally be traced under the skin, the rudiment of leg 3 being distinctly visible.

COPEPODID

Stage I, *R. cornutus*. Length 1·41–1·5 mm.

This stage differs from later stages in having the head scarcely produced, and without rostral processes. The somite of leg 4 is separated, with a pair of dorsal spines, and the somite of leg 5 can be seen under the skin of the terminal somite. The furcal rami are not separated from the somite, and bear five setae. Of the three terminal setae one is inserted rather dorsally and is soft, presumably corresponding to the soft seta of the nauplius, and the inner seta of the left side, which is much the longest in later stages and in the adult, is of the same length as its fellow of the right side. It is a remarkable fact that it is the right spine which is longest in the nauplius.

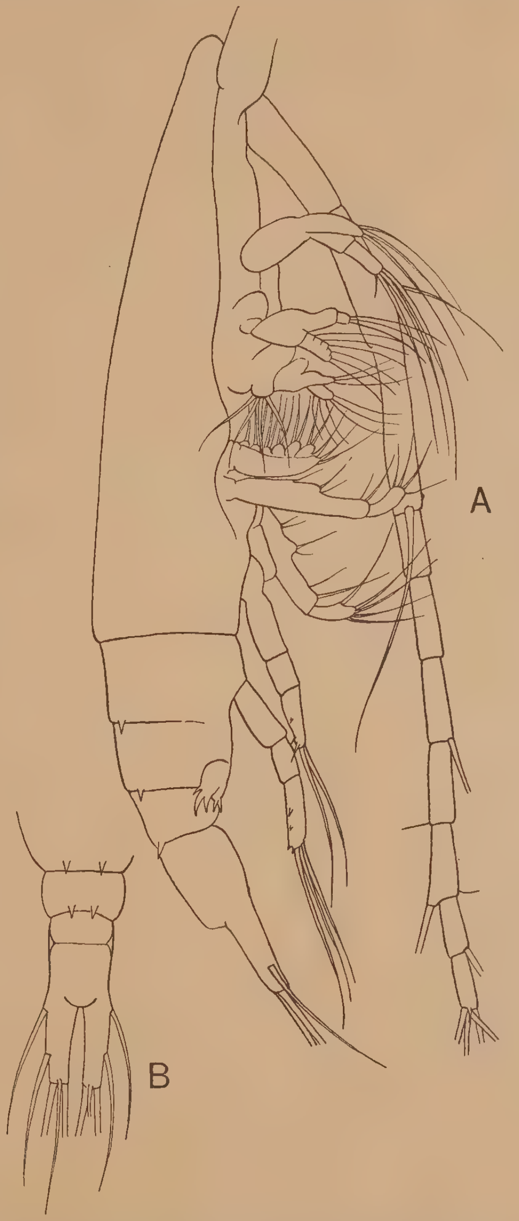

Fig. 7. *Rhincalanus cornutus*. Copepodid, stage I. A, lateral view; B, furcal rami, dorsal view.

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[*Discovery Reports. Vol. IX, pp.* 215–294, *Plates XV, XVI, November,* 1934.]

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INVESTIGATIONS

NEMERTEANS FROM THE SOUTH ATLANTIC AND SOUTHERN OCEANS

By

J. F. G. WHEELER, D.Sc.
Bermuda Biological Station for Research, Inc.

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NEMERTEANS
FROM THE SOUTH ATLANTIC AND SOUTHERN OCEANS

By J. F. G. Wheeler, D.Sc.
Bermuda Biological Station for Research, Inc.

(Plates XV, XVI; text-figs. 1–66)

INTRODUCTION

A LARGE number of the Nemerteans described in this report were examined alive directly after capture, and whenever opportunity occurred they were sketched to show form and colour. This applies particularly to the littoral species from Saldanha Bay, South Africa, and King Edward Cove, South Georgia, where I was engaged on whaling investigations as a member of the Discovery Committee's scientific staff at different periods from 1925 to 1931. Many other specimens were collected in the nets of the R.R.S. 'Discovery', R.R.S. 'Discovery II', and R.S.S. 'William Scoresby' in the course of the investigations. Other members of the staff found time to make sketches of unusual forms, although opportunities were far less frequent at sea, and on most occasions a note of the colour and markings had to suffice.

I wish to express my thanks to Dr Kemp, Director of Research, for his interest and for allowing me to work on the group, to my former colleagues who took especial care in the collection of specimens, and to Professor D. M. S. Watson, who very kindly placed a room and the facilities of his department at my disposal for the completion of the work. That this has been accomplished I owe to my wife who prepared the hundreds of sections—those necessary for comparison with the observations of other workers and those to complete our knowledge of particular species and to make the fullest possible use of the collection.

METHODS

The frequent collections of Nemerteans at South Georgia and from the whaling station at Saldanha Bay were not recorded under station numbers. Most of them were shore collections made in the interval between other work. The dates on which they were made are included in the systematic account. At South Georgia a kelp grapnel made of three shark hooks lashed together was used for tearing kelp roots from the bottom. This was found to be a more efficacious method of capturing undamaged specimens than the dredge or small trawl. The worms collected at sea were taken in a variety of nets to which a key is given below.

The animals sketched and noted in life were preserved and numbered N 1, N 2, N 3 and so on, for work later, since there was little time for section cutting and no opportunity for consulting the literature of the group. The ultimate preserving fluid was 75 per cent alcohol for nearly all specimens, but I found that fixation in Da Fano 1 (cobalt nitrate and formalin—see Lee, 1928, p. 348) and subsequent preservation in 5 per cent formalin worked well with *Lineus corrugatus*, especially the large red-brown form, which does not bleach as readily with this treatment as it does in spirit. Chloral hydrate was the usual anaesthetic. The crystals were added to the sea water in the Petri dish containing the specimen. I found that small forms could be dealt with by sucking them into a glass tube rather smaller in bore than their diameter and holding the tube under hot water running from a tap. When the worms were blown out of the tube into the fixing fluid they contracted very little and not only kept fairly straight but often left their protective mucous coat in the tube and thus facilitated the subsequent examination in cedar oil for deeply embedded eyespots. Bouin and Bouin Duboscq were frequently used as fixing reagents. Corrosive sublimate both hot and cold was tried but was not successful. On one occasion large specimens of *Lineus corrugatus* were immobilized by the natural freezing of the surface layer in the basin left overnight outside the station at South Georgia. The animals were by no means dead although they were at first completely insensitive. As mentioned later in the notes on this species, the slackened musculature of the semi-frozen animals threw light on differences that had been noticed in the body form of preserved specimens.

When the material from the ships was being worked over the numbered series was continued, since very few of the specimens could be identified at sight; and it was used throughout in the numbering of the serial sections. The slides were marked with a diamond N 1, N 2, N 3 and so on, in addition to the serial number in each particular series, and the number was, of course, added to the label replaced with the remainder of the specimen.

The pelagic forms were fixed and preserved in 5 per cent formalin. Before sections were cut the preserved specimens were measured and examined for form, colour and markings. Eyespots were sought for by clearing in cedar or anilin oil. In the armed species the armature was especially looked for, and variations in the number of stylets noted.

Identification with previously described species has, however, not been an easy matter, for variations occur in certain characters that have been used for specific determination, for instance, in the number of nerves in the proboscis and the size of the armature. The state of contraction of the body affects the relative thickness of the body layers and the course of the lateral nerves when they leave the brain. Even the shape of the brain and the position of the organs in relation to it can vary from this cause, though I do not know to what extent. Body form and colour vary considerably in some forms, the outstanding example being *L. corrugatus*, which appears to be the *L. ruber* of the south, judging by the colour differences between individuals that it exhibits when alive and the changes in body form that take place on fixation. If there are difficulties of identification with live animals there are greater difficulties with preserved specimens whose life form and colour are unknown. Only by combining colour sketches and observation in life with anatomical work can the identification of the Nemerteans be made with any degree of certainty.

The complete discontinuity of the African and Falkland sector Nemertean faunas is reflected in this report by treatment in separate sections. It is indeed a striking fact that this discontinuity should be so complete, for the predominant form of the south—*L. corrugatus*—was first collected at Kerguelen, and it might naturally be expected to appear in the fauna of the southern extremity of Africa. Instead there has been found an extension of the Mediterranean fauna to the southern hemisphere as far as Saldanha Bay. This was foreshadowed by the capture of *Carinella annulata* in Simon's Bay near Cape Town, reported by Stimpson in 1856, and it suggests that the littoral Nemerteans depend upon the continuity of land rather than upon ocean currents for their dispersal.

The pelagic forms fall naturally into a separate group on account of their structural peculiarities. Some of these, such as their general transparency and expanded leaf-like form, can be considered as adaptations to their mode of life; but the anomalous position of the male generative organs and the sexual dimorphism exhibited by forms like *Nectonemertes* must be due to deeper causes. The work of Brinkmann on the pelagic forms shows how close is their relationship with the Drepanophoridae and it is curious that this small family, alone among Nemerteans, should have taken to the pelagic habit.

The synonymy of most of the known forms has been thoroughly worked out by Bürger in his magnificent Naples monograph (1895) and in his section (Nemertini, 1904) of *Das Tierreich*. Synonymies are only given in the following report where fresh data warrant a revised opinion on the relationship of previously described species. I have followed Coe (1905) in uniting the Protonemertini and Mesonemertini of Bürger under the order Paleonemertea, and in retaining Hubrecht's order Hoplonemertea for the armed species instead of Metanemertini. The names are less unwieldy than those proposed by Poche (1926). The further division of the Hoplonemertea into Monostilifera and Polystilifera (Brinkmann, 1917) is adopted.

LIST OF STATIONS AT WHICH NEMERTEANS WERE COLLECTED, WITH THE SPECIES OBTAINED

In the list of stations the following symbols represent the various kinds of gear used:

B	Oblique.
BTS	Small beam trawl. Beam 8 ft. in length (2·45 m.): mesh at cod-end ½ in. (12·5 mm.).
DL	Large dredge. Light pattern, 4 ft. in length (1·2 m.).
DS	Large dredge. Heavy pattern, 4 ft. in length (1·2 m.).
N 4–T	Small dredge.
H	Horizontal.
DLH N 7–T	Nets with mesh of 4 or 7 mm. (0·16 or 0·28 in.) attached to back of trawl.
N 70	70 cm. tow-net. Mouth circular, 70 cm. in diameter (27·5 in.): mesh graded, at cod-end 74 to the linear inch.

N 100	1 m. tow-net. Mouth circular, 1 m. in diameter (3·3 ft.): mesh graded. Cod-end of stramin with 11–12 meshes to the linear inch.
N 200	2 m. tow-net. Mouth circular, 2 m. in diameter (6·6 ft.): mesh graded, at cod-end 4 mm. (0·16 in.).
N 450	4½ m. tow-net. Mouth circular, 4½ m. in diameter (14·8 ft.): mesh graded, at cod-end 7 mm. (0·28 in.).
NCS–T	Tow-net of coarse silk, with 16 meshes to the linear inch, attached to trawl.
NH	Hand net.
NRL	Large rectangular net. Frame 8 ft. long and 2¼ ft. wide (2·45 m. × 0·7 m.) with bag of ½ in. mesh (12·5 mm.).
OTC	Commercial otter trawl. Head rope 80 ft. long (24·5 m.): mesh at cod-end 1½ in. (3·8 cm.).
OTL	Large otter trawl. Head rope 40 ft. long (12·2 m.): mesh at cod-end 1¼ in. (3·2 cm.).
OTM	Medium otter trawl. Head rope 30 ft. long (9·14 m.): mesh at cod-end 1¼ in. (3·2 cm.).
RM	Mussel rake
Sh. coll.	Shore collection.
TYF	Young-fish trawl. Mouth about 20 ft. in circumference (6 m.): bag of stramin with 11–12 meshes to the linear inch.
V	Vertical.

R.R.S. 'DISCOVERY' AND R.R.S. 'DISCOVERY II'

2. xi. 25. 6° 55′ N, 15° 54′ W. N 200, 0–800 m.

Pelagonemertes rollestoni, Moseley.
Crassonemertes robusta, Brinkmann.
Nectonemertes kempi, n.sp.

St. 4. 30. i. 26. Tristan da Cunha, 36° 55′ S, 12° 12′ W. DL, 40–46 m.

Cerebratulus fuscus, McIntosh.

St. 27. 15. iii. 26. West Cumberland Bay, South Georgia, 3·3 miles S 44° E of Jason Light. DL, 110 m.

Amphiporus lecointei, Bürger.

St. 39. 25. iii. 26. East Cumberland Bay, South Georgia, from 8 cables S 81° W of Merton Rock to 1·3 miles N 7° E of Macmahon Rock. OTL, 179–235 m.

Amphiporus spinosus, Bürger.
Lineus corrugatus, McIntosh.

N 4–T, 179–235 m.

Tetrastemma esbenseni, n.sp.

St. 42. 1. iv. 26. Off mouth of Cumberland Bay, South Georgia, from 6·3 miles N 89° E of Jason Light to 4 miles N 39° E of Jason Light. OTL, 120–204 m.

Tetrastemma longistriatum, n.sp.

St. 45. 6. iv. 26. 2·7 miles S 85° E of Jason Light, South Georgia. OTL, 238–270 m.

Amphiporus spinosus, Bürger.
Lineus corrugatus, McIntosh.

St. 51. 4. v. 26. Off Eddystone Rock, East Falkland Island, from 7 miles N 50° E to 7·6 miles N 63° E of Eddystone Rock. OTL, 105–115 m.

Tetrastemma georgianum, Bürger.
Lineus corrugatus, McIntosh.

St. 53. 12. v. 26. Port Stanley, East Falkland Island, Hulk of 'Great Britain'. RM, 0–2 m.

Tetrastemma hansi, Bürger.
Lineus corrugatus, McIntosh.

St. 71. 30. v. 26. 43° 20′ S, 46° 02′ W. N 70 V, 1000–750 m. TYF, 2000 (–0) m.

Pelagonemertes rollestoni, Moseley.

St. 72. 1. vi. 26. 41° 43′ 20″ S, 42° 20′ 40″ W. N 450, 2000 (–0) m.

Pelagonemertes rollestoni, Moseley.

St. 76. 5. vi. 26. 39° 50′ 30″ S, 36° 23′ W. N 450, 1500 (–0) m.

Pelagonemertes rollestoni, Moseley.

St. 78. 12. vi. 26. 35° 18′ S, 19° 01′ 10″ W. TYF, 1000 (–0) m.

Pelagonemertes rollestoni, Moseley.

St. 79. 13. vi. 26. 34° 48′ S, 16° 36′ W. N 450, 1000–0 m.

Pelagonemertes rollestoni, Moseley.

St. 85. 23. vi. 26. 33° 07′ 40″ S, 4° 30′ 20″ E. N 450, 2000 (–0) m.

Bathynemertes hubrechti, Brinkmann.
Pelagonemertes rollestoni, Moseley.

St. 86. 24. vi. 26. 33° 25′ S, 6° 31′ E. N 450, 1000 (–0) m.

Bathynemertes hardyi, n.sp.
Pelagonemertes rollestoni, Moseley.

St. 87. 25. vi. 26. 33° 53′ 45″ S, 9° 26′ 30″ E. TYF, 1000 (–0) m.

Nectonemertes mirabilis, Verrill.

St. 89. 28. vi. 26. 34° 05′ 15″ S, 16° 00′ 45″ E. TYF, 1000 (–0) m.

Bathynemertes hubrechti, Brinkmann.
Pelagonemertes rollestoni, Moseley.
Probalaenanemertes irenae, n.sp.

St. 100*c*. 4. x. 26. 33° 20′ to 33° 46′ S, 15° 18′ to 15° 08′ E. TYF, 2500 (–0) m.

Bathynemertes hubrechti, Brinkmann.

St. 101. 14. x. 26. 33° 50′ to 34° 13′ S, 16° 04′ to 15° 49′ E. N 450, 1310–1410 m.

Bathynemertes hubrechti, Brinkmann.

St. 107. 4. xi. 26. 45° 03′ S, 17° 03′ E. N 450, 850–950 m.

Pelagonemertes rollestoni, Moseley.

St. 123. 15. xii. 26. Off mouth of Cumberland Bay, South Georgia, from 4·1 miles N 54° E of Larsen Point, to 1·2 miles S 62° W of Merton Rock. OTL, 230–250 m.

Amphiporus moseleyi, Hubrecht.
A. spinosus, Bürger.
Tetrastemma esbenseni, n.sp.
T. georgianum, Bürger.
Parapolia grytvikenensis, n.sp.
Lineus corrugatus, McIntosh.

St. 140. 23. xii. 26. Stromness Harbour to Larsen Point, South Georgia, from 54° 02′ S, 36° 38′ W to 54° 11′ 30″ S, 36° 29′ W. OTL, 122–136 m.

Amphiporus lecointei, Bürger.
A. spinosus, Bürger.
Tetrastemma georgianum, Bürger.
Cerebratulus larseni, n.sp.

St. 141. 29. xii. 26. East Cumberland Bay, South Georgia, 200 yards from shore, under Mount Duse. BTS, 17–27 m.

Tetrastemma longistriatum, n.sp.

St. 144. 5. i. 27. Off mouth of Stromness Harbour, South Georgia, from 54° 04′ S, 36° 27′ W to 53° 58′ S, 36° 26′ W. NCS–T, 155–178 m.

Tetrastemma gulliveri, Bürger.

St. 156. 20. i. 27. 53° 51′ S, 36° 21′ 30″ W. DLH, 200–236 m.

Amphiporus lecointei, Bürger.

St. 158. 21. i. 27. 53° 48′ 30″ S, 35° 57′ W. DLH, 401 m.

Amphiporus lecointei, Bürger.

St. 159. 21. i. 27. 53° 52′ 30″ S, 36° 08′ W. DLH, 160 m.

Amphiporus lecointei, Bürger.

St. 160. 7. ii. 27. Near Shag Rocks, 53° 43′ 40″ S, 40° 57′ W. DLH, 177 m.

Tetrastemma weddelli, n.sp.

Lineus corrugatus, McIntosh.

St. 163. 17. ii. 27. Paul Harbour, Signy Island, South Orkneys. BTS, 18–27 m.

Tetrastemma longistriatum, n.sp.

Lineus corrugatus, McIntosh.

St. 164. 18. ii. 27. East end of Normanna Strait, South Orkneys, near Cape Hansen, Coronation Island. BTS, 24–36 m.

Lineus corrugatus, McIntosh.

St. 167. 20. ii. 27. Off Signy Island, South Orkneys, 60° 50′ 30″ S, 46° 15′ W. N 4–T and N 7–T, 244–344 m.

Lineus longifissus, Hubrecht.

L. corrugatus, McIntosh.

St. 173. 28. ii. 27. Port Foster, Deception Island, South Shetlands, close to SE shore, near Lake Point. BTS, 5–60 m.

Lineus corrugatus, McIntosh.

St. 175. 2. iii. 27. Bransfield Strait, South Shetlands, 63° 17′ 20″ S, 59° 48′ 15″ W. DLH, 200 m.

Tetrastemma validum, Bürger.

St. 179. 10. iii. 27. Melchior Island, Schollaert Channel, Palmer Archipelago, in creek to S of SW anchorage. DS, 4–10 m.

Tetrastemma validum, Bürger.

St. 182. 14. iii. 27. Schollaert Channel, Palmer Archipelago, 64° 21′ S, 62° 58′ W. N 7–T, 278–500 m.

Amphiporus schollaerti, n.sp.

Baseodiscus antarcticus, Baylis.

St. 186. 16. iii. 27. Fournier Bay, Anvers Island, Palmer Archipelago, 64° 25′ 30″ S, 63° 02′ W. DLH, 295 m.

Lineus corrugatus, McIntosh.

St. 195. 30. iii. 27. Admiralty Bay, King George Island, South Shetlands, 62° 07′ S, 58° 28′ 30″ W. OTM, 391 m.

Amphiporus lecointei, Bürger.

Lineus corrugatus, McIntosh.

St. 256. 23. vi. 27. 35° 14′ S, 6° 49′ E. TYF, 850–1100 (–0) m.

Pelagonemertes rollestoni, Moseley.

St. 283. 14. viii. 27. Off Annobon, Gulf of Guinea, 0·75 to 1 mile N 12° E of Pyramid Rock, Annobon. DLH, 18–30 m.

Lineus geniculatus (Chiaje).

St. 395. 13. v. 30. 48° 26¾′ S, 22° 10′ W to 48° 26½′ S, 22° 06½′ W. N 450 H, 1500–1600 m.

Pelagonemertes rollestoni, Moseley.

St. 405. 4. vi. 30. 33° 50½′ S, 15° 46′ E to 34° 16′ S, 15° 02′ E. TYFB, 2200–0 m.

Pelagonemertes rollestoni, Moseley.

R.R.S. 'WILLIAM SCORESBY'

St. WS 4. 30. ix. 26. 32° 45′ S, 18° 10′ E. DL, 45–47 m.

Nemertopsis tenuis, Bürger.

St. WS 25. 17. xii. 26. Undine Harbour (North), South Georgia. BTS, 18–27 m.

Amphiporus lecointei, Bürger.

Lineus corrugatus, McIntosh.

St. WS 56. 14. i. 27. Larsen Harbour, Drygalski Fjord, South Georgia. NH, 2 m.

Amphiporus spinosus, Bürger.

Lineus corrugatus, McIntosh.

St. WS 62. 19. i. 27. Wilson Harbour, South Georgia. BTS, 26–83 m.

Amphiporus spinosus, Bürger.

Lineus corrugatus, McIntosh.

St. WS 65. 22. i. 27. Undine Harbour (North), South Georgia. Sh. coll.

Amphiporus spinosus, Bürger.

St. WS 73. 6. iii. 27. 51° 01′ S, 58° 54′ W, from 51° 02′ S, 58° 55′ W to 51° 00′ S, 58° 53′ W. OTC, 121–130 m.

Baseodiscus antarcticus, Baylis
Amphiporus spinosus, Bürger.

Lineus corrugatus, McIntosh.
Cerebratulus malvini, n.sp.

St. WS 77. 12. iii. 27. 51° 01′ S, 66° 31′ 30″ W, from 51° 00′ S, 66° 30′ W to 51° 02′ S, 66° 33′ W. OTC, 110–113 m.

Lineus corrugatus, McIntosh.

St. WS 79. 13. iii. 27. 51° 01′ 30″ S, 64° 59′ 30″ W, from 51° 00′ S, 65° 00′ W to 51° 03′ S, 64° 59′ W. OTC, 132–131 m.

Lineus corrugatus, McIntosh.

St. WS 80. 14. iii. 27. 50° 57′ S, 63° 37′ 30″ W, from 50° 58′ S, 63° 39′ W to 50° 55′ 30″ S, 63° 36′ W. OTC, 152–156 m.

Lineus corrugatus, McIntosh.

St. WS 84. 24. iii. 27. 7½ miles S 9° W of Sea Lion Island, East Falkland Island, from 52° 33′ S, 59° 08′ W to 52° 34′ 30″ S, 59° 11′ W. OTC, 75–74 m.

Lineus corrugatus, McIntosh.

Amphiporus falklandicus, n.sp.

St. WS 88. 6. iv. 27. 54° 00′ S, 64° 57′ 30″ W, from 54° 00′ S, 65° 00′ W to 54° 00′ S, 64° 55′ W. OTC, 118 m.

Lineus corrugatus, McIntosh.

St. WS 93. 9. iv. 27. 7 miles S 80° W of Beaver Island, West Falkland Island, from 51° 51′ S, 61° 30′ W to 51° 54′ S, 61° 30′ W. N 7–T, 133–130 m.

Amphiporus lecointei, Bürger.

St. WS 97. 18. iv. 27. 49° 00′ 30″ S, 61° 58′ W, from 49° 00′ S, 62° 00′ W to 49° 01′ S, 61° 56′ W. OTC, 146–145 m.

Amphiporus falklandicus, n.sp.

St. WS 219. 3. vi. 28. 40° 06′ S, 62° 12′ W. NCS–T, 116–114 m.

Amphiporus moseleyi, Hubrecht.

St. WS 225. 9. vi. 28. 50° 20′ S, 62° 30′ W. OTC, 162–161 m.

Amphiporus falklandicus, n.sp.
A. gerlachei, Bürger.
Lineus corrugatus, McIntosh.

St. WS 228. 30. vi. 28. 50° 50′ S, 56° 58′ W. OTC, 229–236 m.

Amphiporus falklandicus, n.sp
Lineus corrugatus, McIntosh.
Cerebratulus malvini, n.sp.

NCS–T, 229–236 m.

Lineus corrugatus, McIntosh.

N 4–T, 229–236 m.

Lineus corrugatus, McIntosh.

St. WS 231. 4. vii. 28. 50° 10′ S, 58° 42′ W. NCS–T, 167–159 m.

Amphiporus inexpectatus, n.sp.

St. WS 237. 7. vii. 28. 46° 00′ S, 60° 05′ W. NCS–T, 148–256 m.

Lineus corrugatus, McIntosh.

St. WS 239. 15. vii. 28. 51° 10′ S, 62° 10′ W. OTC, 196–193 m.

Cerebratulus malvini, n.sp.

St. WS 246. 19. vii. 28. 52° 25′ S, 61° 00′ W. OTC, 267–208 m.

Amphiporus falklandicus, n.sp.
A. gerlachei, Bürger.
Cerebratulus malvini, n.sp.
Lineus corrugatus, McIntosh.

St. WS 248. 20. vii. 28. 52° 40′ S, 58° 30′ W. OTC, 210–242 m.

Amphiporus falklandicus, n.sp.
Lineus corrugatus, McIntosh.

St. WS 249. 20. vii. 28. 52° 10′ S, 57° 30′ W. DLH, 166 m.

Amphiporus gerlachei, Bürger.
Lineus corrugatus, McIntosh.
Cerebratulus malvini, n.sp.

St. WS 302. 6. x. 28. 54° 57′ 20″ S, 31° 49′ 35″ W. N 70 B, 98–0 m.

Amphiporus scoresbyi, n.sp.

St. WS 548. 31. i. 31. 64° 07′ S, 15° 38′ W. N 100 B, 106–0 m.

Amphiporus scoresbyi, n.sp.

St. WS 550. 1. ii. 31. 66° 51½′ S, 15° 24′ W. N 70 B, 121–0 m.

Amphiporus scoresbyi, n.sp.

MARINE BIOLOGICAL STATION, SOUTH GEORGIA

St. MS 67. 28. ii. 26. East Cumberland Bay, 3 cables NE of Hobart Rock to ½ cable W of Hope Point. BTS, 38 m.

Tetrastemma gulliveri, Bürger.
Amphiporus moseleyi, Hubrecht.

St. MS 68. 2. iii. 26. East Cumberland Bay, 1·7 miles S ½ E to 8½ cables SE × E of Sappho Point. NRL, 220–247 m.

Amphiporus spinosus, Bürger.
Lineus corrugatus, McIntosh.

St. MS 70. 9. iii. 26. Maiviken, West Cumberland Bay. Sh. coll.

Tetrastemma esbenseni, n.sp. *T. maivikenensis*, n.sp.

St MS 71. 9. iii. 26. East Cumberland Bay, 9¼ cables E × S to 1·2 miles E × S of Sappho Point. BTS, 110–60 m.

Amphiporus spinosus, Bürger.

NCS–T, 110–60 m.

Amphiporus lecointei, Bürger.

SYSTEMATIC ACCOUNT

PART I. NEMERTEANS FROM SALDANHA BAY, SOUTH AFRICA

Saldanha Bay lies on the west coast of Africa about sixty miles north of Cape Town. The bay is a shallow sandy-bottomed inlet fifteen miles long. From the narrow entrance the bay turns south nearly parallel to the outer coast from which it is separated by a ridge rising in some places into considerable hills. Dredging inside the bay was very unproductive. The Nemerteans described here were collected mainly from the roots of kelp torn from the boulders at low tide. A few were found beneath stones and others in roots and kelp tangles washed up on the beaches. Although the conditions near the two whaling stations were different from those on the outer coast there was no apparent difference in the kelp root faunas except in size. The largest specimens came from the outer coast.

Twelve species were found, eight of which were already known from the Mediterranean and coasts of northern Europe. *Tubulanus nothus* and *Cerebratulus fuscus* were the commonest species, but the yellow *Emplectonema ophiocephala* was also frequently captured. *Lineus geniculatus*, another Mediterranean form, was collected at Annobon Island in the Gulf of Guinea close on the equator. Three new species—*Zygonemertes capensis*, *Tetrastemma nigrolineatum* and *Oerstedia maculata*—are described in the following section.

The extension of range into the southern hemisphere appeared so important that every effort has been made to verify the specific identity of the animals with the previous descriptions. It is for this reason that the colour sketches of the worms in life are reproduced (Pl. XV).

Order PALEONEMERTEA

Genus **Tubulanus**, Renier

Tubulanus nothus, Bürger (Plate XV, figs. 1, 2; Figs. 1–4).

Carinella nothus, Bürger, 1895, p. 527, pl. 1, fig. 12.

Twenty-two specimens of this species were taken from kelp roots from the rocks between tide marks. The lengths ranged from 10 to 20 cm. The corresponding breadths were 0·6 mm. (head 1·0) and 1·0 mm. (head 1·5). One very large fragment of body

2·5 mm. broad was found. The worm to which this belonged must have been 30–40 cm. long. A thin transparent tube was sometimes secreted when the worms had been in captivity for a few hours.

Form and colour in life. The body is round in section, but it tapers and is a little flattened from above down towards the tail. The head is round in outline from above, broader than it is long, and about one and a half times as broad as the body. The proboscis pore is just ventral to the tip of the head and the mouth is a small longitudinal slit immediately behind the junction of the head and neck. There is a large laterally spread group of black pigment specks at the edge of the head on each side of the proboscis pore. The tail is somewhat bulbous; its margin is nearly transparent, and the gut, which shows through, is not swollen.

The general colour is brownish red, fading gradually to yellow at the tail. The underside is paler than the back, more so posteriorly. The shades of red vary from dusky crimson to light yellow red. The colour fades abruptly near the tip of the head and there is here a transverse white mark nearly complete ventrally to form a white ring. The first body ring occurs about the breadth of the head from its posterior end. This ring is a white chevron with its apex pointing back. It is incomplete ventrally. The rest of the body is marked by a series of white annulations also usually incomplete ventrally. The number varies from seventeen to eighty. Some of the earlier rings are complete and the larger ones are formed of two narrow bands placed close together. The interval between the third and fourth body rings is more than double the interval between any other consecutive rings. Traces of lateral longitudinal white lines are found, and sometimes there is a thin mid-dorsal line traceable after the first few rings behind the head and disappearing again at about the fortieth ring.

Form and colour of preserved specimens. On fixing shrinkage takes place, but the body retains its shape to a great extent. The head is flattened but very round in outline from above. There is a fold between head and body in which are hidden the openings of the canals of the cerebral organs (Fig. 1). Side organs are present. They appear as white marks one on each side of the body in the dark brown region behind the third white ring. The body is often somewhat swollen here. The colour of the body anteriorly is light brown on the back, paler beneath. There is a sharp transition after the second white ring to dark dirty brown which is similar dorsally and ventrally. This gradually fades and at the eleventh ring the colour is again light brown. Lateral white lines can just be seen. The patches of eyespecks are sometimes visible as a greyish blur.

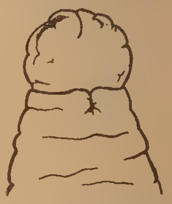
Fig. 1. *Tubulanus nothus*, Bürger. Head of preserved specimen, ventral surface.

Internal structure. The epithelium is thick, especially in the oesophageal region, and contains numerous eosinophile gland cells. Near the tip of the head the distribution of these cells is unequal, there being many ventrally and few dorsally while with the pigment cells the opposite is the case. Head glands and frontal organs are not present. The mouth is evident in transverse section before the brain has disappeared (Fig. 2A). The gut is unbranched.

The vascular system is first seen in serial sections as a single relatively large lacuna, with strands of tissue passing across it vertically, lying above the commencement of the rhynchodaeum at the tip of the head. Farther back the intrusion of the rhynchodaeum causes this lacuna to be divided into two lateral and a median lacuna. The latter has a narrow lumen and lies above the rhynchodaeum. Where the pharyngeal nerves leave the brain the lateral blood spaces are joined beneath the rhynchodaeum by a ventral connecting lacuna and at the same place the laterals are again united with the median dorsal. The latter shortly afterwards disappears. Immediately behind the ventral connecting blood space a pair of small vessels separate off from the laterals. These remain close to the angle of the pharynx, but at the posterior end of the mouth they rejoin the laterals. There are subsequently one or two downward extensions of the laterals forming small loops (Fig. 3). I could not trace the close connection of the vascular system with the excretory tubules described by Oudemans (1885) in *Carinella annulata*. The excretory tubules occur above the lateral vessels and open to the exterior by a single duct high up on the dorsal surface (Fig. 2B).

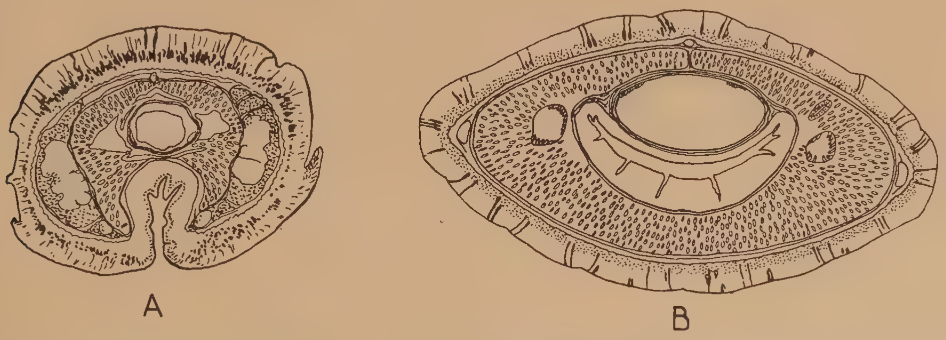

Fig. 2. *Tubulanus nothus*, Bürger. A, transverse section of head at anterior end of mouth; B, transverse section of body at nephridial canal.

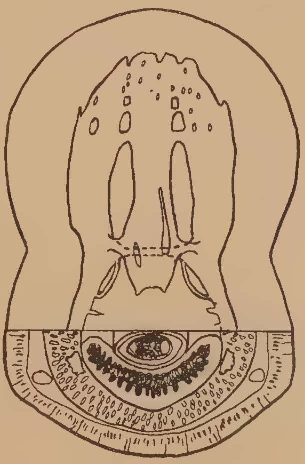

Fig. 3. *Tubulanus nothus*, Bürger. Diagram from a graphic reconstruction showing the vascular system (dorsal).

The nervous system lies between the basement membrane and the circular muscles. The brain consists of two lateral curved plates of tissue with no observed demarcation between cellular and fibrous tracts. The plates are united by a stout ventral commissure, and a little farther back by a slender dorsal commissure. There is little differentiation into dorsal and ventral ganglia until the posterior end of the brain. Anteriorly the brain breaks up into many nerves to serve the tip of the head. Just in advance of the ventral commissure a pair of nerves is given off for the proboscis. Another pair originates from the ventral ganglia after the commissure and innervates the pharynx. A mid-dorsal nerve intersects the dorsal commissure. It passes down the body between the basement membrane and the muscles, and it has been traced forwards for some distance into the head. The lateral nerve stems are united by frequent commissural strands. From the transverse furrows between head and body the cerebral canals pass in on each side directly towards the brain. At the basement membrane they meet and become embedded within a nerve from the dorsal ganglion (Fig. 4). The canal just penetrates the basement membrane but cannot be traced farther.

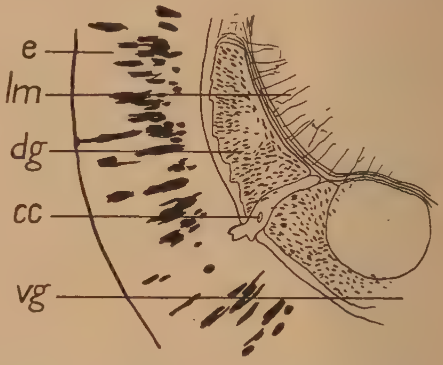

Fig. 4. *Tubulanus nothus*, Bürger. Section showing the cerebral canal entering the nerve from the dorsal ganglion. *e*, epithelium; *cc*, cerebral canal; *dg*, dorsal ganglion; *lm*, longitudinal muscles; *vg*, ventral ganglion.

These worms have been identified with *Tubulanus nothus*, described by Bürger from the Mediterranean, from the form of the head, colour of the body and the arrangement of white rings, the pigmented patches of eyespecks, the side organs, and some anatomical features such as the thickness of the epithelium and the position of the nephridial canals. The penetration of the cerebral canals beyond the basement membrane is not considered of significance. In *T. banyulensis*, whose anatomy according to Bürger (1895) is similar to that of *T. nothus*, the cerebral organ is a finger-like pit which reaches the basement membrane and is innervated from the posterior angle of the dorsal ganglion (*loc. cit.*, p. 526).

It is curious that *T. annulatus* was not taken at Saldanha Bay, for it was described by Stimpson (1856) from Simon's Bay near Cape Town.

Order HETERONEMERTEA

Genus **Lineus**, Sowerby

Lineus bilineatus, Renier, 1804 (Plate XV, fig. 10).

One specimen of this characteristically marked species was taken in August from a kelp root attached to a granite boulder on the outer shore near Eland Point—the end of the southern arm of the bay. The length was between 15 and 20 cm., but the specimen was damaged. The breadth of the head was 0·6 mm. Eggs were present.

Form and colour in life. The body is soft, somewhat flattened and slim. The head is not distinctly marked off from the body; it is flat, obtusely pointed and wider at half length than the anterior part of the body. The tip is slightly notched. No eyes are visible.

The colour is light brown with a double white line down the back from the tip of the head to the tip of the tail.

Form and colour of preserved specimen. In spirit the worm is white and no trace can be seen of the white lines. The cephalic slits are very long. The mouth is a small round aperture opposite the posterior ends of the cephalic slits.

No eyes could be seen after clearing in anilin oil.

Lineus geniculatus (Chiaje, 1828) (Fig. 5).

Two specimens (N 69) were taken at St. 283 off Annobon in the Gulf of Guinea. This was in August 1927. They were practically identical in size: length 27·5 cm.; breadth 0·55 cm.; thickness 0·15 cm.

Form and colour of preserved specimens. The body is very flattened, the head blunt in outline from above and the tail pointed. The mouth is a longitudinal slit 7 mm. long (Fig. 5).

The colour is brownish dorsally and ventrally with complete white annulations—fifty-three in one specimen, fifty-six in the other. I could find no trace of longitudinal markings and no sign of eyes: but of the latter eighty-eight were afterwards counted in the sections embedded in the tissue of the head at the edges of the cephalic slits. They were most numerous at the tip of the head but occurred as far back as the brain.

The head glands stain markedly with haematoxylin. They are scattered in two symmetrical areas on each side of the rhynchocoel, passing away on each side above and below the cephalic slits. They disappear from the sections before the brain appears. The cephalic organs are somewhat small.

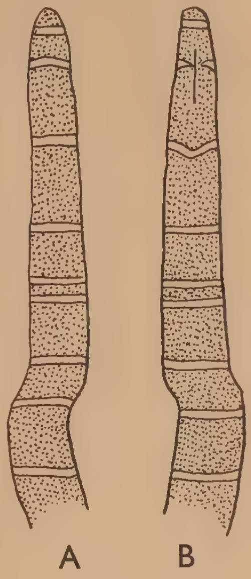

Fig. 5. *Lineus geniculatus* (Chiaje). A, dorsal; B, ventral surface of the preserved specimen. × 1.

A full description of this species is given by Bürger (1895), and to this the specimens from Annobon exactly conform.

Lineus ruber (O. F. Müller), 1771 (Plate XV, fig. 4; Fig. 6).

Twenty-three specimens were taken between July and September from the shore between tide-marks. Most of the worms were found near the whaling stations under stones on the mud, but some occurred in kelp roots from rocks on the shore outside the Bay. The largest worm was 14·0 cm. long, with a breadth of 1·0 mm.; the smallest was 5·0 cm. long, breadth 0·5 mm.

Form and colour in life. The body is round and tapers gradually at the tail. The head is rather flat and broader than the succeeding part of the body. The snout is broad and mobile. The cephalic slits are long and pale. The mouth is a small elongated slit with pale lips far back on the ventral surface of the head. The colour in life is brown, deepest anteriorly. The tail is very pale. Behind the head both dorsally and ventrally there is a large undefined reddish mark. A series of pale rings is visible on the body in some specimens. In an 11 cm. worm seventeen were counted. The tip of the snout is pale. The eyes are variable, but not more than ten were found on each side. Usually there were five in a line at the edge of the pigment.

In one specimen there was a row of minute pores showing pale on each side of the body nearer the dorsal than the ventral side. The row, marking the openings of the genital sacs, commenced about one-third of the length of the body from the anterior end.

Form and colour of preserved specimens. The colour is bleached in spirit to a greyish white. No eyes are visible. The proboscis pore is terminal and the anterior end of the mouth is at the level of the posterior ends of the cephalic slits (Fig. 6A).

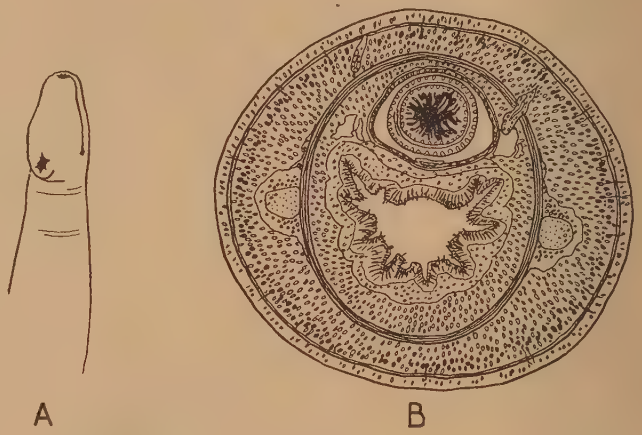

Fig. 6. *Lineus ruber*, O. F. Müller. A, head of spirit specimen, ventro-lateral; B, transverse section of body at the passing of the excretory tubules to the exterior.

Internal structure. Frontal organs were not seen although the tip of the head was sectioned. The muscle layers are arranged typically (Fig. 6 B).

There is a single vascular lacuna dorsal to the rhynchodaeum in the head. This divides and the two lacunae thus formed split up after the region of the ganglia into numerous vessels round the gut. The dorsal vessel protrudes into the rhynchocoel.

The excretory tubules bulge into the large blood vessels on each side of the rhynchocoel. They occur a considerable distance behind the brain. Only one duct was found leading to the exterior on each side and it opened high up on the dorsal surface (Fig. 6B). From the persistence of the tubule in the last sections cut in series of this worm it is probable that further ducts were present. The number given by Punnett (1901) is from six to twelve on each side.

The cephalic slits continue nearly to the tip of the snout and they disappear posteriorly as soon as the canal has entered the head. The fibrous tissue of the dorsal ganglion divides posteriorly into an upper branch which quickly disappears, and a lower which becomes invested with the cerebral organ and forms the posterior lobe of the brain. This lies almost free in a blood sinus at its hinder end. When the ventral ganglia merge into the lateral nerves they shift laterally from their position directly beneath the dorsal ganglia.

The genital sacs (in the female) open high up laterally.

The green form of *L. ruber* was described by Stimpson (1856 and 1857–8) from specimens collected in Simon's Bay under the name *Cerebratulus oleaginus* (*Meckelia olivacea* in the earlier paper). The identification with *Lineus ruber* was suggested by Bürger (1895). *L. ruber* has been recorded from Madeira by Langerhans (1880).

Genus Cerebratulus, Renier

Cerebratulus aerugatus, Bürger, 1892 (Plate XV, fig. 5; Figs. 7, 8).

The anterior end of a Lineid worm was found in a kelp root torn from the rocks between the whaling stations. The length was 5·5 cm., the breadth of the head about 1·0 mm. A distinct shallow groove was noticed in the mid-dorsal line of the head. The diverticula of the gut were very regularly placed opposite one another.

Form and colour in life. The body is soft and a little flattened. The head is lance-shaped, flat and broader at the level of the ends of the cephalic slits than the succeeding part of the body. The cephalic slits are very long. There are no eyes. The mouth is small, placed mid-ventrally behind the ends of the cephalic slits. The body is reddish brown towards the anterior end, fading to yellow posteriorly. The greater part of the head is white. A vague red patch is visible dorsally and ventrally where the body colour fades at the back of the head. In spirit the colour is brownish.

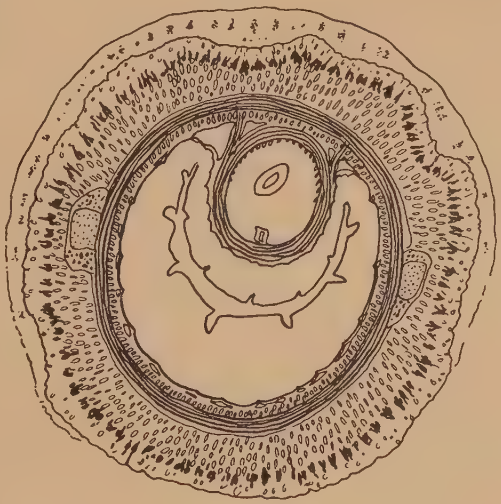

Fig. 7. *Cerebratulus aerugatus*, Bürger. Transverse section through the body to show the relative thickness of the muscle layers.

Internal structure. The tip of the snout was unfortunately missed in sectioning so that the frontal organs are not known. The head glands are thin and scattered. They extend back as far as the brain. No trace of eyes could be seen. In the stomach region the epithelium is about as thick as that part of the longitudinal muscles into which the cuticular glands penetrate. The outer longitudinal muscle layer is from three to four times as thick as the circular layer, while the inner longitudinal layer is thinner than the circular. There is no diagonal layer. The circular muscles of the rhynchocoel are about as thick as those of the circular layer of the body (Fig. 7).

There is a vascular loop in the head. Posterior to the brain the dorsal vessel protrudes into the rhynchocoel and a number of blood spaces of varying size surround the stomach (Fig. 7). The excretory system is not known.

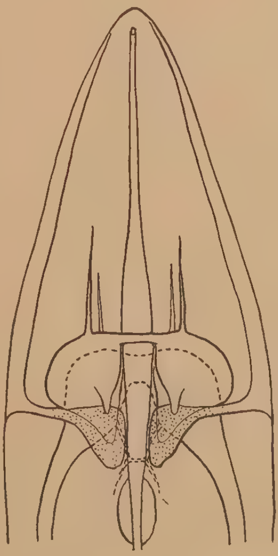

Fig. 8. *Cerebratulus aerugatus*, Bürger. Diagram from a graphic reconstruction of the brain and cerebral organs

The relations of the brain and cerebral organs are shown in Fig. 8. The fibrous tissue of the dorsal ganglia is about twice as extensive as that of the ventral and the brain is large for the size of the head. The ventral commissure is wider than the dorsal. The dorsal ganglia divide posteriorly into upper and lower branches. The small upper branches taper away rapidly while the lower become included in the cerebral organs which swell to form substantial lobes lying almost free at their hinder ends in blood sinuses formed from the lateral and median vessels. The ventral ganglia become the lateral nerves beneath the cerebral organs and leave their positions on either side of the rhynchocoel to pass down the body. Neurochord cells were observed in the cellular tissue of the inner face of the ventral ganglia just posterior to the ventral commissure.

The cephalic slits are apparent very near the tip of the head. They do not extend posteriorly beyond the cerebral canals, which pass in directly opposite the lower cornua of the dorsal ganglia.

As far as I am able to judge from the incomplete specimen the identification of this worm with *C. aerugatus* is justified.

Cerebratulus fuscus, McIntosh, 1873 (Plate XV, fig. 8; Figs. 9, 10).

Eighteen specimens were taken during August and September. This species was fairly common in the kelp roots between tide-marks both inside and outside the Bay. The lengths varied between 2·3 and 3·5 cm. with breadths of 0·8 and 1·4 mm. Specimens with eggs were collected on August 14.

Form and colour in life. The body is a little flattened from above down. The head is flat, not distinctly marked off from the body, and it tapers to a blunt snout. The cephalic slits are very long and the mouth is small, placed at the end of the head behind the brain. The small eyes vary in number and are deeply embedded. There are usually ten visible on each side; five together near the tip of the snout, the others in a line farther back. A caudal appendage is present. The range of colour is from pale buff to pink or light red on the back with scattered reddish brown splashes mainly near the middle line and less definite and paler at the posterior end of the body. The underside is pale flesh colour.

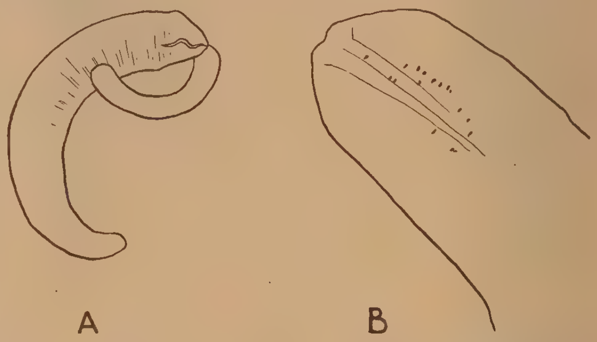

Fig. 9. *Cerebratulus fuscus*, McIntosh. A, sketch of the preserved specimen, × 4; B, lateral view of the head to show the eyespots.

Form and colour of spirit specimens. An outline sketch of a preserved specimen is shown in Fig. 9A. Neither eyes nor markings are visible. On clearing in anilin oil the eyes can be seen (Fig. 9B). The colour is completely bleached.

Internal structure. Frontal organs are present. The head glands are fairly well developed. They are more numerous dorsally than ventrally and they can be seen dorsally in transverse sections almost to the posterior end of the brain. They stain deeply with haematoxylin but not so deeply as the subepithelial gland cells. Eosinophile cells are numerous in the epithelium. Farther back on the body many of the subepithelial cells stain with eosin.

The rhynchocoel is long, but the proboscis is attached in the first half of the body.

Two vascular lacunae close to the rhynchodaeum can be traced back to the anterior insertion of the proboscis. They reappear as a median lacuna ventral to the rhynchocoel; and from this lacuna arises the dorsal vessel and a dorsal lacuna which later divides into two lateral lacunae in which lie the cerebral organs. Posterior to the brain the vascular system has not been traced.

The brain is very large (Fig. 10). There is a strong upper branch to the dorsal ganglion posteriorly. This upper horn disappears before the lower, which is invested with the cerebral organ and forms the posterior lobe of the brain. A dorsal nerve arises from the dorsal commissure. On the intrusion of the mouth the ventral ganglia separate and from this point they may be called the lateral nerves. Previous to this the ganglia are close together and directly beneath the dorsal ganglia. They curve outwards sharply to take up their lateral positions. A pair of nerves is given off before the separation for the innervation of the pharyngeal muscles.

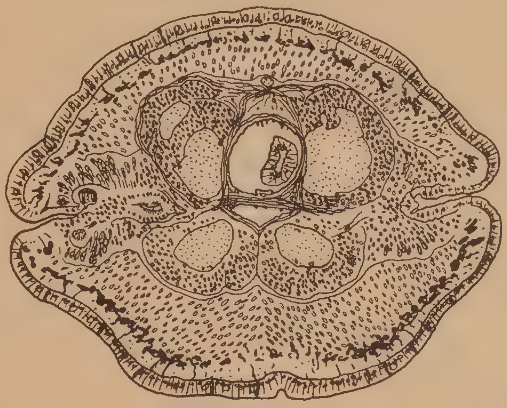

Fig. 10. *Cerebratulus fuscus*, McIntosh. Transverse section of the body at the extreme anterior limit of the mouth.

The differences between these specimens and the worms described by McIntosh (1873) are so slight that I have no hesitation in identifying them as *C. fuscus*. The pigmentation is more distinct, but worms of the same species even more distinctly marked have been described by Joubin (1894). Bürger (1895) gives the body form as characteristic—the tail being very wide. Evidently this is a variable character for McIntosh's description is "slightly tapered towards either extremity". The internal structure bears out the identification, although I have not been able to find neurochord cells in the ganglia.

An autotomized specimen (N 129) of a small heteronemertean with a caudal appendage was collected at Tristan da Cunha (St. 4). No colour note was made. The approximate length was 30·0 mm.

The body is round in section. The head is flat with long cephalic slits (3·0 mm.) and a straight slit-like mouth 1·5 mm. long. The colour is uniformly greyish. The long proboscis is protruded. The anatomical details of this form are interesting in that they are definitely against the inclusion of this form with the *Cerebratulus* of the Falklands (*C. malvini*). The peculiarly wide cephalic slits are present and the eyes, which are absent in *C. malvini*, are here evident, confined however near the tip of the head. Well-marked frontal organs are present. Head glands are very thin and scattered. The brain is large and is similar to that of *C. fuscus*. There is a strong dorsal branch to the massive dorsal ganglion. In the absence of notes on the form and colour during life I hesitate to separate this form from *C. fuscus*, which anatomically it closely resembles.

Order HOPLONEMERTEA

Sub-order *MONOSTILIFERA*

Genus **Emplectonema**, Stimpson

Emplectonema ophiocephala (Schmarda), 1859 (Plate XV, fig. 14; Figs. 11, 12).

Thirty-eight specimens were captured between June and September in kelp roots from rocks between tide-marks inside and outside the Bay. The usual length was about 25 cm., breadth 1–1·5 mm. The largest worm was 40 cm., greatest breadth 2·0 mm. The majority were mature and in consequence rather swollen. In one specimen the gut was full of grey mud. Damaged worms were frequent as the body is very soft.

Form and colour during life. The body is long and soft. A distinction can be drawn between head and body, as the posterior end of the flattened lanceolate head is slightly broader than the succeeding part of the body. Anteriorly the head tapers to an acute snout. Neither mouth nor cephalic slits can be seen, but occasionally a pair of faintly marked sloping lateral grooves are apparent behind the head. Deep transverse wrinkles appear when the body contracts. The colour is generally yellow, but may vary from lemon yellow or yellow-brown to reddish or orange. The head and tail are paler than the rest of the body. There are elongated groups of small eyespots on each side of the head—about twenty in each group—spreading out somewhat posteriorly. In small worms (6–7 cm. long) there are from four to twelve eyes visible on each side. The brain shows as a pinkish, brownish or greyish bilobed structure through the skin just behind the groups of eyespots (Fig. 11A). The genital sacs show white through the skin.

Form and colour of preserved specimens. The worms frequently contract violently and break up during preservation. In spirit they are bleached, and the form is often distorted by bulges and knot-like swellings. The eyes and cephalic slits are not visible. The proboscis pore is just beneath the tip of the head. On clearing in anilin oil the brown or black cup-shaped eyes can be seen. They vary greatly in number from seven or eight on each side to thirty. When seen partly from the side (Fig. 11B) or from above, each group can be divided into two rows. The eyes of the outer row open forwards, those of the inner row backwards and upwards. There are usually more eyes in the inner row, but they are smaller than those of the outer.

Internal structure. The oesophagus opens into the rhynchodaeum. The gut is capacious. Behind the rhynchocoel it occupies the entire body cavity. The anterior caecum does not extend far forwards (it does not appear in either of my two series of sections). Frontal organs are absent. The head glands consist of a thin solid strand, staining with eosin, dorsal to the rhynchodaeum, extending back, thinning out and disappearing before the separation of the oesophagus and rhynchodaeum. Near the tip of the head there are small round eosinophile cells scattered among the muscle strands. These apparently open into the rhynchodaeum. The tissues of the body cavity stain deeply with haematoxylin or carmine, giving the impression of a thick mucus in which deeply staining granules are embedded.

The epithelium is very thick. The basement membrane is a little thicker than the circular muscle layer. It is homogeneous in appearance and stains with eosin. The longitudinal muscle layer is somewhat thicker than the epithelium and the fibres are packed in conspicuous bundles. The ganglia are enveloped in a coat of longitudinal fibres. In the body behind the brain this muscle layer splits into bundles which pass gradually outwards and rejoin the longitudinal layer of the body. The eyes are just inside the muscles, embedded in the connective tissue.

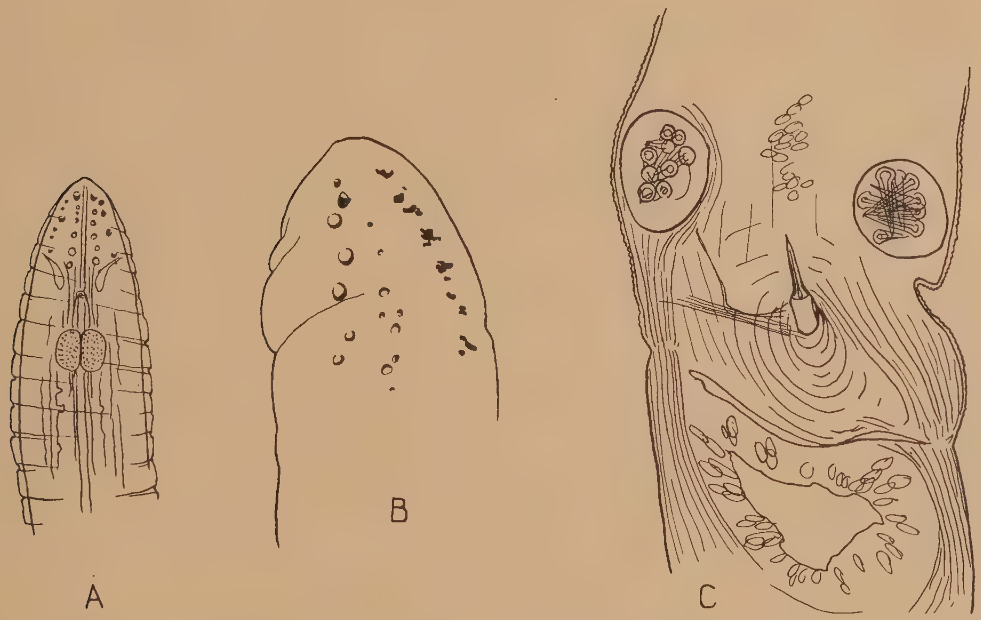

Fig. 11. *Emplectonema ophiocephala* (Schmarda). A, sketch of head cleared in cedar oil; B, head cleared in cedar oil, dorso-lateral view to show the eyespots; C, armature, cleared in cedar oil.

The rhynchocoel does not extend beyond the anterior third of the body. The proboscis is short and thin. Both rhynchocoel and proboscis are greatly restricted by the closely opposed ganglia. The armature appears to vary. Two accessory stylet reservoirs are always present, but the number of stylets differs. In two worms of nearly the same size taken at the same time, the accessory stylets numbered one and two in one, and eight and nine in the other (Fig. 11C). A third specimen possessed two and three stylets. There is a stout main stylet mounted on a slightly hour-glass-shaped base shorter than the stylet itself.

Vascular system. There are two lateral vessels in the head. They have not been traced at the ganglia, but the blood is responsible for the colour of the brain in the living animal, so the vessels are broken up into fine branches. Directly behind the brain there are two vessels at the outside upper corners of the stomach and two lower than these near the lateral nerves. Farther back in the body there are two laterals near the nerve trunks and a dorsal median vessel above the gut.

Excretory system. The convoluted tubules lie beside the stomach and gut. They extend forwards to just behind the brain. The posterior limit of the tubules was not seen in either series of sections, but two pairs of efferent ducts—the posterior pair almost 2 mm. behind the anterior—were observed. The ducts pass over the lateral nerves, then downwards and outwards through the body wall.

Nervous system. The brain is peculiarly compact (Figs. 11A, 12). The ganglia are very close together, so that the rhynchocoel and proboscis are much constricted where they pass through the brain. There is little distinction between dorsal and ventral ganglion. The ventral commissure is extraordinarily deep and broad. In the specimen examined the brain was 0·4 mm. long and 0·25 mm. thick. The ventral commissure was 0·27 mm. long and 0·125 mm. thick—half the thickness of the brain and nearly three-quarters of the length. The dorsal commissure was 0·08 mm. long. The lateral nerves leave the brain at right angles to the long axis. They make a sharp turn back to pass laterally down the body inside the longitudinal muscles. A marked swelling of the nerves occurs after they leave the brain and before they turn.

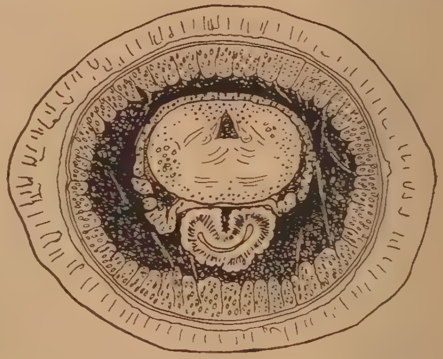

Fig. 12. *Emplectonema ophiocephala* (Schmarda). Transverse section through the brain.

The cerebral organs are very small. They are sac-like organs lying some distance in front of the brain and are connected with the dorsal ganglion of each side by a stout nerve which penetrates the muscular sheath and reaches the ganglion about one-third of the length of the brain from the anterior end. The cerebral canals open to the exterior near the tip of the snout (Fig. 11A).

Ommatoplea ophiocephala, Schmarda (1859), is considered to have been a *Eupolia* by Bürger (1895, p. 27). Schmarda refers the genus *Ommatoplea* to Ehrenberg and this is synonymous with *Eunemertes* (Bürger, 1895, p. 13). Schmarda's account of the worms found under stones and in sand in Table Bay, South Africa, corresponds fairly well with the description given above. His specimens were larger. He mentions the length as 1 m., the greatest breadth 10 mm., the colour as lemon yellow or golden brown, and the (eight) eyes in two lines on both sides of the head. The "small egg-shaped subterminal" mouth is evidently the opening of the rhynchodaeum, and the terminal pore may have been the opening of the head gland.

In many ways these specimens are similar to *Eunemertes antonina*, Quatrefages. The peculiarities of the brain which characterize this Mediterranean species, the swelling and course of the lateral nerves, the position and size of the cerebral organs and canals are alike in both. Even the darkly-stained connective tissue of the cavity of the body, remarked upon by Bürger (1895, p. 547), appears in these Saldanha Bay forms. The chief difference lies in the uniform rose red or carmine tint of *E. antonina*, which is considered characteristic of the species by Hubrecht (1879, p. 231). The colour is noted also by Joubin (1894, p. 206). The body of *E. antonina* appears to be considerably more slender than this South African worm, and the main stylet in the armature of the latter does not bear the proportion 3 : 1 to its base, although it is certainly longer than the base in the specimens I have examined. Taking these facts into consideration I do not consider the identification of these worms with *E. antonina* is justified, but there seem to be good grounds for considering that the same forms were described by Schmarda under the specific name *ophiocephala*.

Genus **Nemertopsis**, Bürger

Nemertopsis tenuis, Bürger, 1895 (Plate XV, fig. 7).

Eight specimens were found at different dates in attached kelp roots from the granite boulders between tide-marks on the outer coast. The lengths ranged from 10 to 41 mm., the corresponding breadths being 0·3 and 0·4–0·5 mm.

Form and colour in life. The body is very thin, almost Nematode-like. The head is not distinct from the body, and the tail tapers acutely. The four small eyes occur in close-set pairs, the posterior pair being very far behind the anterior. The colour is yellowish brown and the gut shows pale through the skin. Yellow-red blood vessels, especially the dorsal vessel in the posterior half of the body, are evident in some specimens.

Form and colour of preserved specimens. Considerable shrinkage takes place after preservation. The colour is bleached. On clearing in anilin oil the brown cup-like eyes can be faintly seen.

Internal structure. The oesophagus opens into the rhynchodaeum just posterior to the cerebral organs and in front of the brain. The contents of the cells of the stomach wall stain deeply with haematoxylin. The anterior caecum has no forward branches.

The epithelium is as thick as the longitudinal muscle layer, and the basement membrane is about half as thick as the circular muscle layer. The longitudinal muscles are not conspicuously divided into bundles. A compact head gland is present, opening dorsally just above the proboscis pore. The head gland reaches the brain.

The rhynchocoel extends about one-third of the body length. The proboscis has ten nerves. The armature is not known.

There are two definite blood vessels in the head forming a loop beneath the head gland. At the ganglia these vessels become difficult to trace, but posterior to the excretory tubules there are two vessels lateral to the rhynchocoel and a median vessel above the gut. This median vessel is formed originally of branches from the laterals.

The convoluted excretory tubule is packed closely behind the dorsal ganglion and opens to the exterior by a single duct above the lateral nerve.

The brain is not peculiar. The ventral commissure is thicker than the dorsal, and the lateral nerves leave the brain sharply and turn back as sharply after undergoing a knot-like enlargement. The eyes are embedded within the longitudinal muscle layer. The second pair occurs immediately before the brain. The cerebral organs are very small. They lie in front of the brain and their canals open behind the first pair of eyes into a transverse lateral groove that occurs on each side of the head.

Nearly ripe eggs were present in some specimens. The eggs are shed just above the lateral nerves.

In two particulars—the yellow rather than rose colour of the body and the presence of a head gland—this description differs from that of Bürger.

Another specimen (N 109) was identified from sections. It was 10 mm. long, 0·3 mm. broad, bleached and coiled. This was taken at St. WS 4 in 40 m.

Genus **Amphiporus**, Ehrenberg

Amphiporus pulcher, Johnston, 1837 (Plate XV, fig. 13).

Two specimens (N 36) were taken from attached and washed-up kelp roots in September 1926 on the southern point of Saldanha Bay. The lengths and breadths were 3·5 cm., 1·5 mm., breadth of head 1·0 mm.; 4·2 cm., 1·7 mm. (swollen with eggs).

Form and colour in life. The body is round anteriorly, somewhat flatter and wider posteriorly. The head is a little flattened, almost semicircular in outline from above, but has a slight snout. The mouth, proboscis pore and cephalic slits are not visible, but a chevron groove can sometimes be seen at the back of the head. The colour is pinkish yellow or buff, lighter anteriorly and deepest on the back. The ganglia show red through the skin. About ten eyes are visible on each side in no definite order, but there is usually a row of four in a line nearly parallel to the edge of the head from the tip to the widest part.

Form and colour of preserved specimens. In spirit the worms are white and contracted. Cephalic grooves appear as vertical furrows at the sides behind the head, curving forwards ventrally. The proboscis pore is ventral to the tip of the snout in a furrow that passes vertically round the head.

Internal structure. Well developed head glands are present but they do not reach the brain. There is a strand close above the rhynchodaeum which stretches back beneath the vascular loop almost to the ganglia, and more diffuse glands among the muscles of the head which become restricted near the ganglia to the sides of the body cavity inside the longitudinal muscles. The duct of the head gland opens just ventral to the tip of the snout. The eyes are embedded deeply in the tissues of the head.

The epithelium is thinner than the longitudinal muscles and about three times as thick as the basement membrane and circular muscles together. The basement membrane is twice as thick as the circular layer and appears to contain fibres. The epithelium contains a large number of eosinophile cells.

The oesophagus opens into the rhynchodaeum in front of the brain. The stomach walls are not much folded and most of the cell contents stain deeply with haematoxylin. The anterior caecum has forwardly directed branches, two of which extend beyond the others on each side of the rhynchocoel. They do not approach the brain. The proboscis is attached about the half length of the body. The rhynchocoel extends the whole length. The accessory armature consists of two reservoirs each with five or six stylets. There are eleven nerve strands in the proboscis.

Two blood vessels, one on each side of the rhynchodaeum, form a loop in the head. They are lost at the ganglia, but reappear as two lateral vessels above the nerves. A dorsal vessel above the gut is connected by a branch on each side with the lateral.

The excretory tubules are packed close behind the ganglia. From them single ducts on each side pass back above the lateral nerves and vessels and turn outwards some distance behind the brain.

The dorsal commissure is longer and thinner than the ventral. The ventral ganglia, becoming the lateral nerves, shift very gradually outwards. The dorsal ganglia taper posteriorly and the cerebral canals pass in beneath them and widen into the cerebral organs which are thus wedged between dorsal and ventral ganglia behind the ventral commissure. The organs swell as the dorsal ganglia diminish in size, and when the latter join them they are somewhat flattened bodies larger in cross-section than the lateral nerves at the same point. They are rounded posteriorly, but extend back some distance from the point of fusion with the fibres of the dorsal ganglia.

There seems little doubt about this identification. Graphic reconstruction of the head of the specimen sectioned gives a plan of the vascular and nervous systems identical with that figured by McIntosh (1873), and in all particulars the description corresponds with those of other workers.

Another specimen (N 127) was collected by Mr E. R. Gunther from a sponge brought to the surface from 292–402 m. by a trawler from Cape Town on July 8, 1927. This was noted in life as "flesh-coloured".

The preserved specimen was 27 mm. in length, 7 mm. broad and 3·5 mm. thick. The body was stout and flattened from above down. It was sectioned and identified with this species.

Genus **Zygonemertes**, Montgomery

Zygonemertes capensis, n.sp. (Plate XV, figs. 3, 6, 12; Figs. 13–16).

Variations in colour and form were responsible for five descriptions and sketches of this worm (N 26, N 29, N 33, N 38, N 39). These five have been reduced to three fairly constant colour variations which are described and figured separately.

(1) *Green form.* Twenty-seven specimens were taken from attached and washed-up kelp roots inside and outside the south arm of the Bay. The largest worms were 80 mm. long, 1·5–2·0 mm. in breadth; the smallest 14 mm. long, 0·5 mm. in breadth.

In life the body is slightly flattened and soft. The head is flat, broader than the succeeding part of the body and somewhat diamond-shaped in outline from above. The snout is blunt. The tail is pointed and a little bulbous. Neither mouth nor cephalic slits can be seen. The colour on the back is green, greyish green, or light brown tinged with green. The underside is buff or yellowish. The head appears lighter than the body but is, in fact, more distinctly green, and there shows faintly upon it a pale mid-dorsal longitudinal streak. The posterior end of the body is yellowish. Under low magnification black specks can be seen scattered thickly over the head and body. The eyes are many and small. They occur in four sectors over the head, leaving three narrow paths devoid of eyes diverging from one another from the tip of the snout (Plate XV, fig. 3). As the eyes are embedded in the muscles of the head the number seen in life—about twelve in the inner and eighteen in the outer group on each side—is not only variable but is nothing like the total number, because the posterior groups only become visible on clearing in anilin or clove oil.

A specimen similar to this form, 50 mm. long and 1·2 mm. broad (breadth of head 0·75 mm.), was collected at the end of July. A transverse groove encircled the body a short distance behind the head. The eyes were very indistinct. The ganglia showed brown through the skin and the swollen body was tinged with orange. This specimen was a ripe male.

(2) *Brown form.* Three specimens from kelp roots from the outer rocks were similar in size and shape to the green form but were of a light brown colour very distinctly tinged with mauve. A slight speckling of reddish brown occurred, especially anteriorly. The ganglia showed green through the skin. The eyes were irregular in size and arrangement (Plate XV, fig. 12).

(3) *Colourless form.* Twenty-four specimens were taken. The largest was 34 mm. long and 0·5 mm. broad. They were almost transparent at the edges of the body and white or very faint yellow when seen against a dark background. The eyes appeared to be even more irregular than in the brown form. They were collected from inside and outside the Bay (Plate XV, fig. 6).

The fifth colour variant was similar to the colourless forms, but there was a pale brown collar in the region of the ganglia. One specimen only was taken.

Form and colour of preserved specimens. Shrinkage takes place but the body form is retained. In about half the specimens the proboscis is partially protruded. Both the coloured forms retain a hard bright blue-green colour on the back, and this colour resists spirit for at least two years. The underside of preserved specimens is pale yellow, and the colourless forms are white. No eyes can be seen. The proboscis pore is situated just ventral to the tip of the head. Cephalic furrows can be seen curving round dorsally as they pass back from the snout.

On clearing in anilin oil three groups of eyespots can be seen on each side of the head. Two of these groups are the ones already mentioned. The third group are dorso-lateral on the body immediately behind the head. The eyes are small, variable sized and cup-shaped. Those of the outer anterior group—about fifty—open forwards; those of the inner anterior group—forty to forty-five—open rather backwards; and the posterior set—thirty or so—open mainly laterally (Fig. 13). In the uncoloured forms the eyespots themselves are bright green.

Internal structure. No frontal organs could be recognized in sections. The epithelium is almost as thick as the longitudinal layer of muscles and between two and four times as thick as the basement membrane and circular muscles together. These last are about equal in thickness. There are many large gland cells in the epithelium; they may be the black specks of the living animal. The sickle-shaped bodies similar to those first described by Marion (1872) are found in the epithelium of all forms; they appear to resist acid and are yellowish brown in colour (Fig. 14). The fibre-containing basement membrane stains deeply with haematoxylin, and numerous minute ducts can be seen penetrating it, especially on the head. Often the glands are themselves in the membrane but sometimes they are more deeply placed in the longitudinal muscles. Farther down the body they are much less frequent.

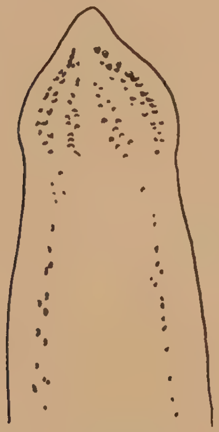

Fig. 13. *Zygonemertes capensis*, n.sp. Head, dorsal surface, cleared in anilin oil to show the three groups of eyespots.

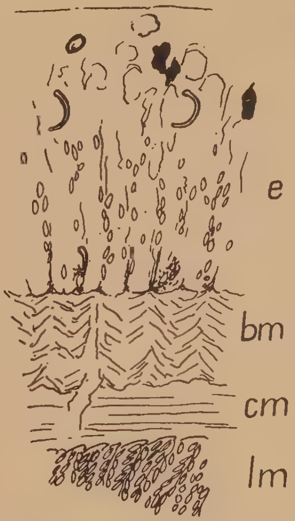

Fig. 14. *Zygonemertes capensis*, n.sp. Part of a transverse section highly magnified. *e*, epithelium containing sickle-shaped bodies; *bm*, basement membrane; *cm*, circular muscle layer; *lm*, longitudinal muscle layer.

The oesophagus opens into the rhynchodaeum before the brain. In the region of the ganglia the oesophagus widens. Farther back it opens into the stomach with dark-stained granules in the cells of the folded walls and on each side appears a branch of the anterior caecum. These two diverticula do not reach the brain.

There is a vascular loop in the tip of the head. In the brain region the lateral vessels are widened, their walls become definite and they are connected with the dorsal vessel above the gut. The three vessels pass down the body and join again above the gut just before the insertion of the rhynchocoel into the body wall. The excretory vessels lie above the lateral nerves behind the brain. A single duct on each side opens to the exterior opposite the nerves. The ganglia are not peculiar, but the brain is rather large (Fig. 15 A). The lateral nerves give off branches which pass round the rhynchocoel, and at the posterior end of the body they join above the gut anterior to the anus. The cerebral canals open ventro-laterally a little way behind the opening of the oesophagus into the rhynchodaeum. The organs are small and do not reach the ganglia, but a stout nerve has been traced to them from the brain.

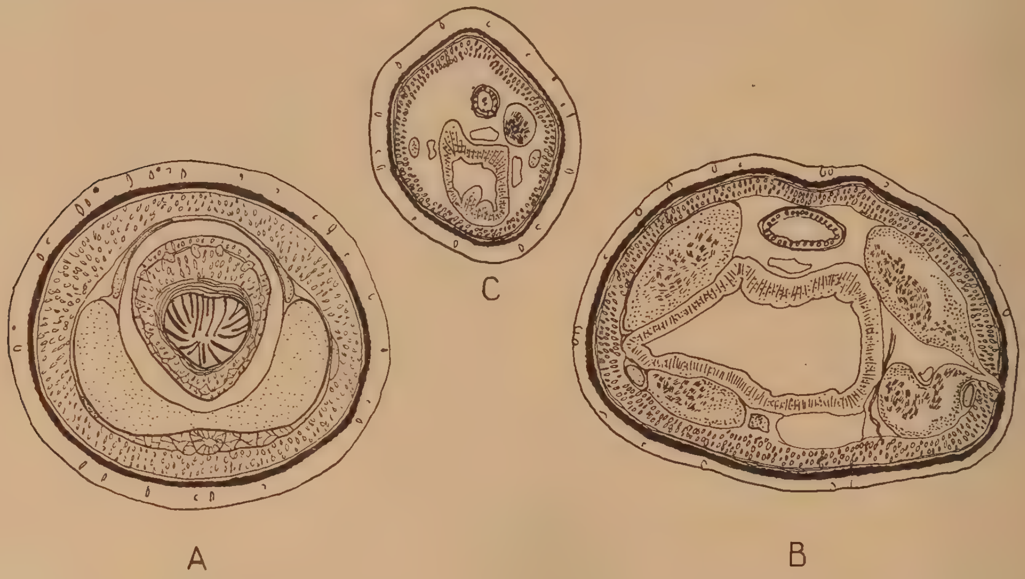

Fig. 15. *Zygonemertes capensis*, n.sp. A, transverse section across the head at the level of the ventral commissure; B, transverse section across the body at about half its length to show the opening of the genital sacs; C, transverse section 0·025 mm. from tip of tail.

In some specimens the protruded proboscis is nearly as long as the body, in others it is about a quarter of the body length. These differences are probably due to different states of contraction and extension of the proboscis and body on fixing. There are thirteen nerves. That part of the proboscis posterior to the armature is shorter than the anterior part and is inserted in the rhynchocoel at about one-third or half the length of the body. The rhynchocoel extends to the posterior end of the body (Figs. 15B and C). The armature (Fig. 16) consists of a main stylet on a base of unusual length, and two accessory reservoirs each with two, three or four stylets. Often one of the accessory stylets is incomplete. The base of the main stylet varies between two and a half to five times the length of the stylet. Measurements of three armatures from green and brown forms are given below:

Main stylet (mm.) ...	0·115	0·156	0·133
Base of stylet (mm.) ...	0·518	0·714	0·301
Accessory stylet (mm.)	0·164	0·182	0·130

In the uncoloured forms the difference in length between base and main stylet is not so marked:

Main stylet (mm.)	0·078	0·050
Base of stylet (mm.) ...	0·117	0·084

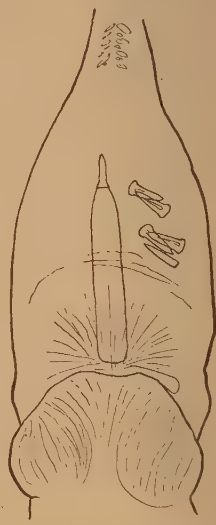

Fig. 16. *Zygonemertes capensis*, n.sp. Armature of the green form (cleared in anilin oil).

Both sexes of each form were examined. Ova are shed by separate ducts forming when required through the dorsal muscles and epithelium. Spermatozoa are shed just above the lateral nerves (Fig. 15B). Ripe eggs are present in August.

The examination of sections showed that the original identification of these worms with *Emplectonema echinoderma*, Marion, was inadmissable on account of the extent of the rhynchocoel. It is evident that there is a close relationship with *Zygonemertes virescens* (Verrill) Montgomery, but there are also differences—the larger size, the absence of a terminal sense organ, the relatively larger base to the main stylet, the larger number of eyes, the greater number of nerves in the proboscis—which justify the establishment of a new species.

Genus **Tetrastemma**, Ehrenberg

Tetrastemma candidum, O. F. Müller, 1774 (Plate XV, fig. 15).

T. incisum, Stimpson, 1856.

Thirty-five specimens were captured in attached and washed-up kelp roots from the rocks at the entrance of the Bay. The lengths were usually about 10 mm., breadth 0·5 mm., but sometimes they reached 16 mm., breadth 0·75 mm.

Form and colour in life. The body is round in section, tapering posteriorly to the tail. The head is slightly broader than the body. The mouth is not visible. On each side of the head there is a nearly vertical groove and occasionally a second pair of grooves can be seen immediately behind the head.

The colour is pale buff or light brown. The edges of the body appear transparent, and the gut is visible through the skin. There are four eyespots forming the corners of an almost perfect square. The posterior pair is just behind the anterior grooves.

Form and colour of preserved specimens. In spirit the ratio of length to breadth is altered—an 11 mm. worm being 1·5 mm. broad, and a 9·5 mm. worm 1·2 mm. broad. The colour is bleached, and the eyespots cannot be seen either before or after clearing in clove or anilin oil.

Internal structure. The oesophagus and rhynchodaeum coincide and the common opening is immediately ventral to the tip of the head. The head glands are thin and small. They just reach the brain. There are lateral and dorsal strands, the former joining together near the tip of the head to form a ventral strand. They open at the extreme end of the snout.

In the region of the anterior caecum the epithelium is about two and a half times as thick as the circular muscle layer and the basement membrane together, while the circular muscle layer is a little thicker than the basement membrane. The longitudinal muscle is thin. The eyes are visible in sections deeply sunk in the muscles of the head.

Branches from the anterior caecum extend as far forward as the brain.

The cephalic slits are deep grooves almost completely ventral near the tip of the head. They pass back, upwards and outwards and become canals sinking into the longitudinal muscles. Glandular tissue encloses the canals and a nerve from each dorsal ganglion passes into the organ.

The dorsal ganglia are smaller than the ventral. There are ten nerves in the proboscis.

No excretory vessels or ducts could be traced.

The armature consists of a main stylet on a base somewhat longer than itself and two accessory reservoirs. In one worm three accessory stylets were present in each reservoir but in others there were only two. The lengths were as follows:

Main stylet 0·067 mm., accessory stylet 0·058 mm., base 0·077 mm.

This species appears to correspond with *Tetrastemma incisum*, Stimpson (1856). I can see no reason for separating it from *T. candidum*, Müller, since in size and shape of the body and head, and in the absence of markings it agrees closely with a colour variant of this species.

Tetrastemma nigrolineatum, n.sp. (Plate XV, fig. 9; Fig. 17).

A single specimen was taken in July from a kelp root inside the Bay. The length was 25 mm., breadth about 0·3 mm.

This slender worm appears to be rectangular in section, and the head is wedge-shaped when seen from the side. There are no eyespots and neither mouth nor cephalic slits are visible. The colour is whitish green, with two parallel black lines passing down the back from tip of snout to tip of tail. At the head these lines are thinner than they are on the body.

In spirit traces of the double dark line can be seen.

Internal structure. Head glands are absent. The epithelium is about as thick as the longitudinal muscle layer. The basement membrane and circular muscles are thin. The former is thinner than the latter and stains with haematoxylin. Brown pigment granules are present at the base of the epithelial cells where the dark lines can be seen in life. There are no traces of eyespots.

The oesophagus opens into the rhynchodaeum, and the common pore is ventral to the tip of the head. The narrow oesophagus opens into a folded stomach with deeply staining walls just posterior to the dorsal ganglia. The unbranched anterior caecum ends a long way behind the brain.

The proboscis extends well into the posterior half of the body, and the rhynchocoel into the posterior third. The armature consists of a single main stylet on a reddish brown base and two reservoirs with seven or eight accessory stylets. Some of these are incomplete.

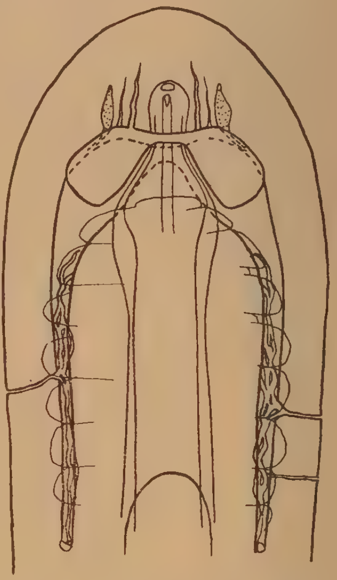

Fig. 17. *Tetrastemma nigrolineatum*, n.sp. Diagram from a graphic reconstruction of the brain, cerebral organs, excretory and alimentary systems.

The two blood vessels in the head form a loop. They lie one on each side of the rhynchocoel in the brain region and subsequently dorsal to the lateral nerves, after connecting up with the dorsal vessel in the ventral wall of the rhynchocoel. Just before the excretory ducts pass to the exterior the lateral vessels shift round inside the lateral nerves and continue down the body beneath them. The excretory system consists of the usual convoluted tubules close above the lateral nerves. In front of the anterior caecum a duct leads to the exterior on each side above the nerve (on one side of this worm there were two ducts).

The brain is large for the size of the head, but it is compact and well defined. There is a large proportion of fibrous tissue in both ganglia. The dorsal ganglia are smaller than the ventral and the dorsal commissure is thinner and in advance of the ventral. The cerebral organs are small sacs opening near the proboscis pore on the ventral surface. They just reach the brain. The relations of brain, cerebral organs, excretory and alimentary systems are shown in Fig. 17.

This worm is very similar to *Nemertopsis bivittata*, Chiaje, with the exception of the four eyes, but its internal structure shows that its affinities are with *Tetrastemma* rather than *Nemertopsis*.

Genus **Oerstedia**, Quatrefages

Oerstedia maculata, n.sp. (Plate XV, fig. 11; Fig. 18).

Five specimens (N 40) were collected from kelp roots from the outer beaches in September. The lengths were 6, 7 and 8 mm. with breadths of 0·25–0·4 mm. The largest specimen was 12 mm., breadth 0·4 mm. This species exhibited a semi-rigid form like that of *O. dorsalis*, Abildg., and when in movement the head was often held upon one side. In one of the worms this feature seemed permanent. A double eyespot was observed in one specimen and ripe eggs were present in one.

Form and colour in life. The body is round in section and short, with little distinction between head and tail. The snout is blunt. Four large eyespots are apparent, but, as shown later, the eyespots are double. They are placed in pairs one behind the other at a greater distance than in *Tetrastemma candidum*. The colour is pale buff with one or two indefinite and irregular small brown spots on the back.

In spirit specimens the eyespots and markings are not visible, but the eyes on clearing can be seen faintly as brownish marks.

Internal structure. The epithelium in the stomach region is somewhat thicker than basement membrane and the two muscle layers together. The basement membrane is homogeneous and thicker than the circular muscles. The longitudinal muscle layer is not divided into bundles. The oesophagus opens into the rhynchodaeum near the opening of the latter to the exterior. A large unbranched anterior caecum is present, reaching almost as far forwards as the brain. The proboscis is long and the rhynchocoel extends almost the whole length of the body. The head glands form a compact mass, spreading posteriorly and just reaching back to the ganglia. They open above the proboscis pore.

The armature consists of a main stylet and two accessory stylet reservoirs each with two stylets.

The vascular system is of the usual type—two lateral vessels and a dorsal vessel above the gut. In the brain region the laterals are above the lateral nerves, but just behind the brain they pass below and continue beside the gut (Fig. 18A).

There is a convoluted excretory tubule on each side close behind the ganglia opening above the lateral nerves.

The ganglia are large in proportion to the size of the animal. Both commissures are thin. The fibres of the dorsal ganglia (lower posterior angle) continue into the lateral nerves and retain their individuality down the body. They are separated from the ventral fibres by cellular tissue. The lateral nerves unite before the anus above the gut. There are ten nerves in the proboscis.

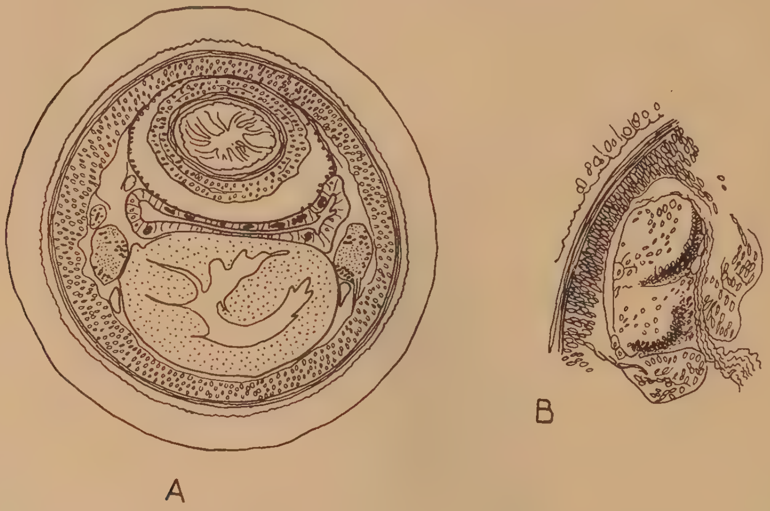

Fig. 18. *Oerstedia maculata*, n.sp. A, transverse section of the body in the region of the stomach and anterior caecum; B, part of a transverse section of the head, highly magnified, to show the double eyes.

The cerebral organs are small sacs lying a long way in front of the brain, each with a short narrow canal leading to the exterior on the ventral surface near the proboscis pore. There is no external furrow.

The eyespots are double (Fig. 18B). The anterior pair is close behind the cerebral organs and the posterior pair directly in front of the dorsal ganglia.

The specimen sectioned was a male with ripe sperm.

PART II. NEMERTEANS FROM THE FALKLAND ISLANDS, SOUTH GEORGIA AND THE ISLANDS AND BANKS OF THE WESTERN SOUTH ATLANTIC OCEAN

Of the twenty-five species here described only the littoral forms from South Georgia and the Falklands were sketched in life. The remainder were taken in nets at sea and only occasional colour notes were made. Twelve species had been previously described and six of these are here figured for the first time in colour. The South Georgia specimens were mainly collected from the roots of kelp off the Point, King Edward Cove, close to the whaling station of the Cia Argentina de Pesca. The water here was from 4 to 6 m. deep and the bottom was very muddy and greasy from the years of whaling activity at the head of the cove. Throughout the area *Lineus corrugatus*, McIntosh, was by far the most common species.

On the Burdwood Bank, off the Falklands, South Shetlands and South Orkneys, specimens were brought up by the ships while dredging or trawling. The deepest capture was *Amphiporus lecointei*, Bürger, from 401 m. at St. 158.

No representatives of the Paleonemertea were taken. The Hoplonemertea and the Heteronemertea are strongly represented, the former by nine species each of *Tetrastemma* and *Amphiporus*, the latter by one or more species of the genera *Baseodiscus*, *Parapolia*, *Lineus* and *Cerebratulus*.

Order HETERONEMERTEA

Genus **Baseodiscus**, Diesing

Baseodiscus antarcticus, Baylis, 1915 (Figs. 19, 20).

One specimen (N 59) was taken at St. 182 in 278–500 m. No record exists of its appearance in life. Two large specimens taken at St. WS 73 were found among the collection and identified with the previous specimen. These were accompanied by a note: "Larger specimen 28 cm. long and 0·5 cm. wide. Both of a pinkish colour, deeper along the mid-dorsal and mid-ventral lines". The specimen from St. 182 is a small nearly cylindrical worm, blunt at both ends, 25 mm. long and 2 mm. in diameter. The colour is very pale brown with no trace of markings. The larger specimen from St. WS 73 is 300 mm. long and 6·5 mm. wide, the smaller 130 mm. long and 3·5 mm. wide. Both are pale yellow-brown with no markings.

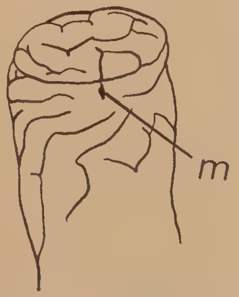

Fig. 19. *Baseodiscus antarcticus*, Baylis. Head of preserved specimen, ventral surface, to show the annular furrow and the mouth (*m*).

The following notes may be added to the description given by Baylis (1915):

The body is soft and flattened except at the head. Both head and tail are blunt; in fact, when the worms have been preserved it is difficult to identify the head, it resembles so much a broken end of the body. The back is very wrinkled, the small deep wrinkles giving almost a matted appearance. Down the centre of the back is a raised ridge with a longitudinal groove on each side of it. Ventrally the wrinkling is mainly in the form of longitudinal furrows of which the median ones are the deepest. There is a furrow at the back of the head and the mouth is just behind this in the middle line (Fig. 19).

Internal structure. There appear to be frontal organs as shallow pits at the corners of a depression at the tip of the head. Head glands are not evident in the early sections, but about midway between the proboscis pore and the brain they appear, stained palely with haematoxylin, scattered through the musculature, especially ventrolaterally. Dorsally they are thin, also mid-ventrally, and they disappear altogether before the brain.

The position of the brain, cerebral organs, proboscis pore and mouth can be seen in the graphic reconstruction (Fig. 20). The proboscis is thin and also its sheath. The mouth is small and rounded. The epithelial layer is thin and the cutis deep. The gelatinous tissue developed between the bundles of the outer longitudinal muscle layer (Baylis) is extraordinarily well-marked in the larger specimens and is responsible for the unusual degree of wrinkling of the skin.

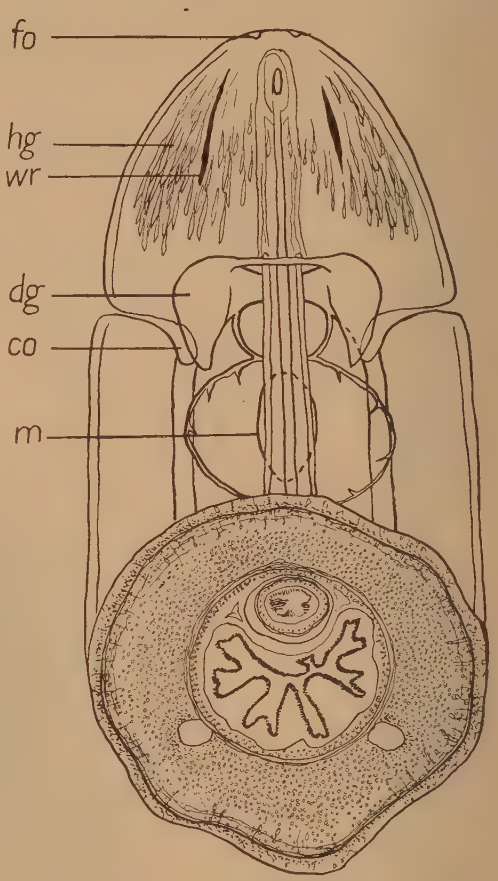

Fig. 20. *Baseodiscus antarcticus*, Baylis. Diagram of the organs at the anterior end of the body and head. *co*, cerebral organ; *dg*, dorsal ganglion; *fo*, frontal organ; *hg*, head gland; *m*, mouth; *wr*, deep wrinkles on the dorsal surface of the head. (From a graphic reconstruction.)

Genus Parapolia, Coe

Parapolia grytvikenensis, n.sp. (Plate XVI, fig. 14; Figs. 21, 22).

One specimen (N 43) was collected at St. 123 from 230–250 m. The contracted length in life was 4 cm., breadth 0·27 cm.

Form and colour in life. The body is stout and cylindrical in the passive and contracted condition in which the single specimen was found. The head is acutely pointed, flattened, and is separated from the body by a slight "neck". The tail is blunt. The mouth can be seen as a small longitudinal slit some way back from the tip of the head. Neither cephalic slits nor eyespots can be seen. The colour is pinkish brown, darkening towards the tail.

Form and colour of spirit specimen. The length is 2·8 cm., the greatest breadth 0·35 cm. The body is round in section anteriorly, flattened from above down posteriorly. The head is small and pointed and is separated from the body by a shallow circular depression. The mouth is mid-ventral—a small slit with definite lips—situated in the depression and on each side are small vertical furrows (Fig. 21 A).

Anatomy. Frontal organs are present but head glands appear to be completely missing. The proboscis pore is a narrow slit placed ventrally not far from the tip of the head. Before its appearance in transverse section the vascular lacunae are present.

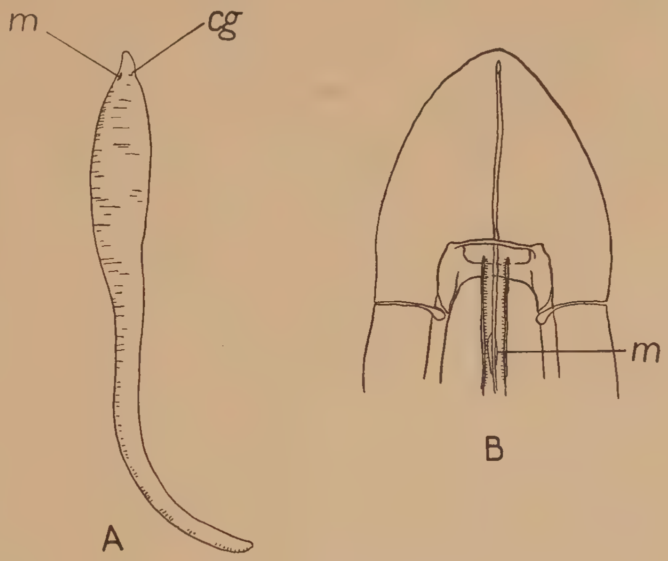

Fig. 21. *Parapolia grytvikenensis*, n.sp. A, sketch of preserved specimen; *m*, mouth; *cg*, cephalic slit. B, outline of the head (from above) from a graphic reconstruction showing the brain, cerebral organs, and the position of the mouth (*m*).

The body layers can be seen in Fig. 22. The glands in the cutis are few and inconspicuous. The epithelium is thin. The slender proboscis has definitely the Lineid arrangement of muscle layers.

The brain is small and ill-defined, the fibrous part mingling with the muscles. The cerebral organs are also small. They lie close above the ventral ganglia where these are passing laterally into the lateral nerves. I could trace no direct connection between the cerebral organs and the dorsal ganglia. The organs open to the exterior by fine lateral canals (Fig. 21 B).

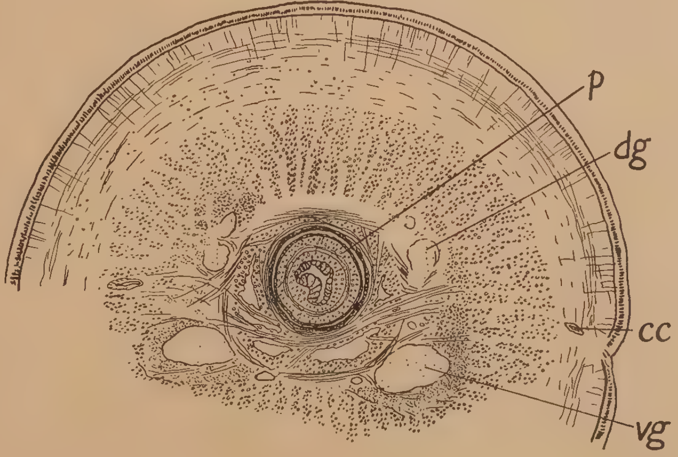

Fig. 22. *Parapolia grytvikenensis*, n.sp. Part of a transverse section of the head at the posterior end of the brain. *cc*, cerebral canal; *dg*, dorsal ganglion; *p*, proboscis; *vg*, ventral ganglion.

The anterior end of the mouth follows directly the disappearance of the cerebral organs from transverse sections. There are no eyes.

The identification of this specimen with the genus *Parapolia* rests on the Lineid structure of the proboscis and the absence of head slits. The specific name is taken from Grytviken, the name of the original headquarters of the whaling industry of the South Atlantic, in Cumberland Bay, South Georgia.

Genus **Lineus**, Sowerby

Lineus corrugatus, McIntosh, 1887 (Plate XVI, figs. 16, 19, 20, 21; Figs. 23–27).

Cerebratulus corrugatus (McIntosh), Hubrecht, 1887; *C. steinini*, *C. validus*, *C. subtilis*, Bürger, 1893; *C. magelhaensicus*, Bürger, 1895; *C. Charcoti*, Joubin, 1908; *Lineus autrani*, Joubin, 1908.

Some hundreds of Lineid worms conforming in life to the type *L. corrugatus*, McIntosh, were taken from South Georgia and others were collected at stations made off the Falklands and the South Shetland Islands. A great number were examined alive and notes and sketches made of them at the time. A number of methods were used in fixing and preserving them. Identification with the descriptions given by earlier workers has proved a difficult task, and the conclusion I have reached is that there is one species present, widely distributed and very common in this part of the Southern Ocean and as variable in form, colour and size as *L. ruber* of European waters.

The following description covers the external appearance of all the specimens in life.

The length is from a few centimetres to fifty or more at South Georgia. Considerably larger specimens were collected at the South Shetlands. When in motion a 52 cm. worm was 3 mm. across the broadest part of the head; a 17·5 cm. worm was 1·5 mm. across the body.

The colour varies from light fawn to greyish black through all shades of fawn, light reddish brown, greenish brown, dark red-brown and brownish black. The ventral side is nearly always paler than the dorsal. Two white tags from near the posterior ends of the cephalic slits pass upwards. The incomplete band thus formed is occasionally complete and very rarely double. Sometimes the tags are faintly marked and sometimes they are absent. The tip of the snout is white, and the cephalic slits are lined with white. The white lining may extend the whole length or it may stop at the tags. The body colour usually fades towards the tail. The colour of the head may be slightly greenish and sometimes a reddish patch may be apparent on the body just posterior to the head. Occasionally there is a trace of a light median line on the snout. The cephalic slits have a white granular appearance inside and a trace of red at the hinder end. Irregular light transverse wrinkles are present especially towards the posterior end.

The body is slightly flattened. The head is distinctly flat and somewhat wedge-shaped. A "neck" is visible when the animal is moving. The mouth is large and no traces can be seen of pigmented eyespots. The darker colours are more general in the smaller worms, and the white tags, besides being very much more evident by contrast, appear to be invariable.

The specimens in spirit or formalin can be divided into three types: (i) Large pale specimens contracted—often into a spiral with the tail inside—and wrinkled both longitudinally and transversely to a greater or less extent at different parts of the body. The colour that remains is usually stronger dorsally than ventrally (Fig. 23A). These may have a long slit-like mouth and firm unprotruded lips or the mouth may be a small slit with pursed lips (Figs. 23B, D, E). (ii) Elongated uncontracted forms of very pale uniform colour, much thinner than type (i). The mouth is very large and the lips are thin, protruded and distorted (Fig. 23F). (iii) Small specimens coiled spirally with small mouths and pursed lips. The colour is dark and often the same dorsally and ventrally (Fig. 23C).

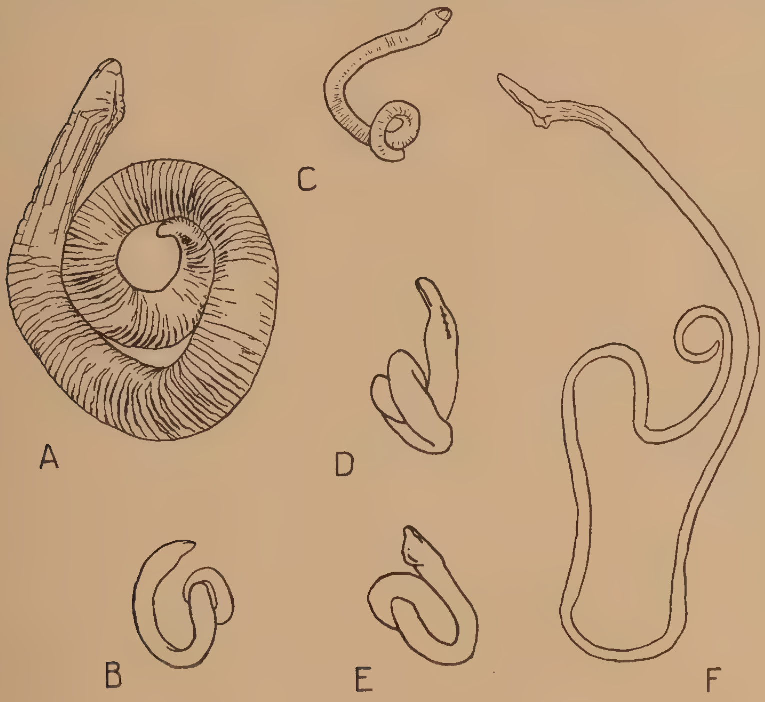

Fig. 23.

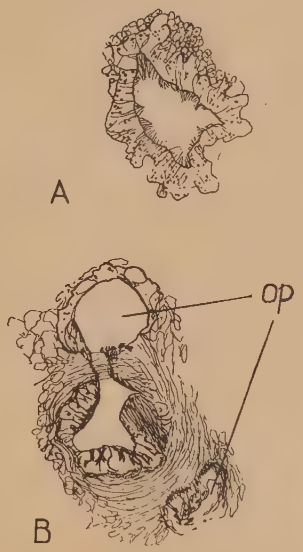

Fig. 24.

Fig. 23. *Lineus corrugatus*, McIntosh. A, preserved specimen of the large type (i); B, E, specimens of type (i) with the mouth pursed, the former from Port Stanley, Falkland Islands; D, specimen of type (i) with the mouth unpursed; C, type (iii); F, the elongated type (ii).

Fig. 24. *Lineus corrugatus*, McIntosh. A, transverse section of the rhynchodaeum near the proboscis pore; B, section of the rhynchodaeum farther back than A, showing the outpushings (*op*). × 175.

That these differences were not discernible in life can be judged from the fact that the different types were sometimes preserved together from the same haul which suggests individual reactions to the fixing fluids. In April 1927 many brownish, reddish and black specimens were dredged from red algae and stones in King Edward Cove. There was no apparent difference in shape, although it was noticed that the brown forms were perhaps rather stouter in build than the others. The roots and worms were left outside the Biological Station for the night, during which the surface water in the pan froze after being mixed with snow. On the following day some of the worms had relaxed and taken on the appearance of type (ii), but on killing with hot water they contracted to the type (i) like the remainder of the catch.

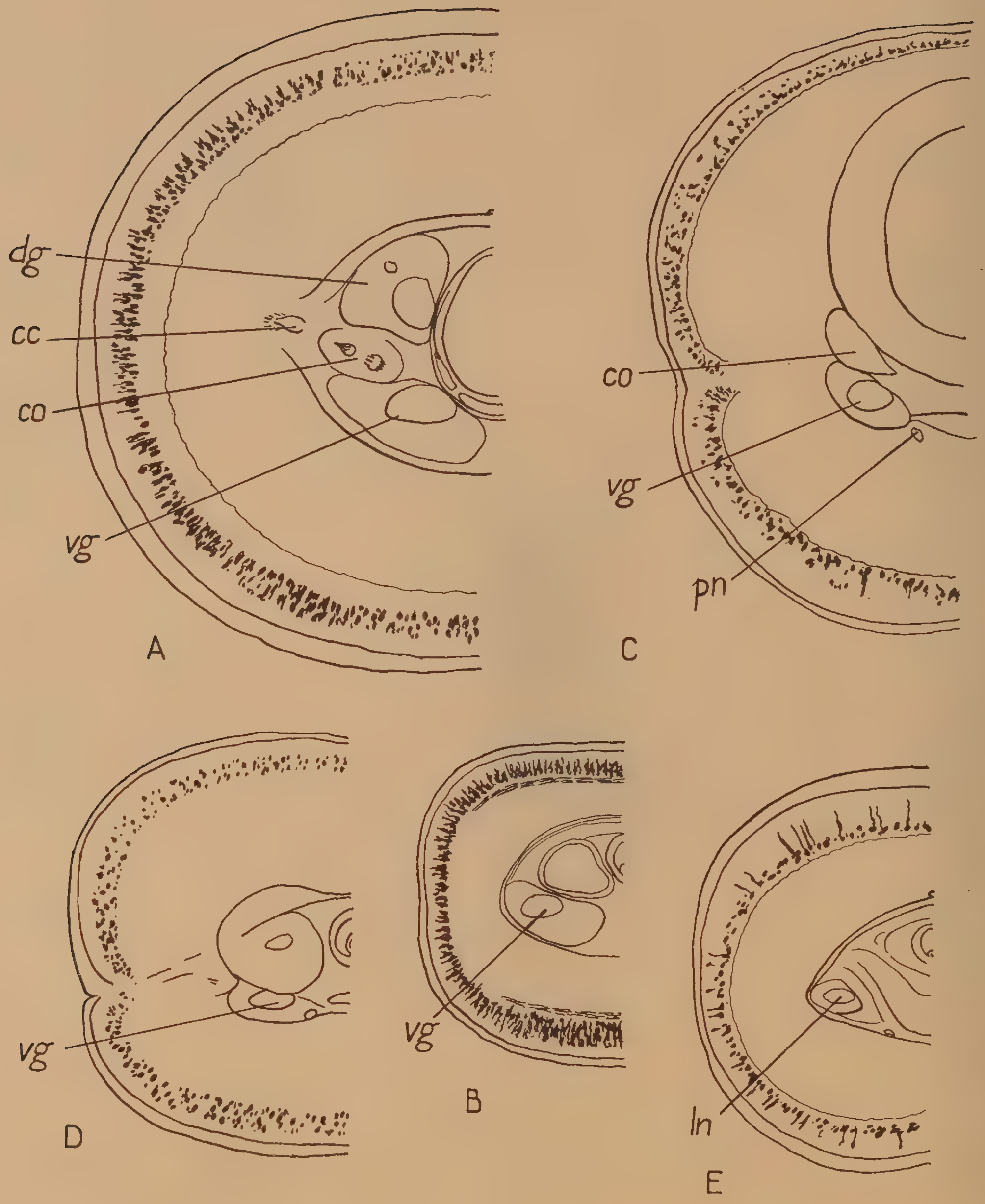

Fig. 25. *Lineus corrugatus*, McIntosh. A series of diagrammatic half-sections at the level of the extreme anterior end of the mouth. A, type (i); B, type (i) corresponding to B of Fig. 23; C, type (iii); D, type (i) corresponding to D and E of Fig. 23; E, type (ii). *cc*, cerebral canal; *co*, cerebral organ; *dg*, dorsal ganglion; *ln*, lateral nerve; *pn*, pharyngeal nerve; *vg*, ventral ganglion.

An investigation was made of the length of the mouth and of the cephalic slits relative to the body length in the preserved specimens with the interesting result that the apparently very large mouth of type (ii) is actually smaller for the length of the animal than it is in either of the other types.

Internal anatomy. Frontal organs are present. The head glands are thin and scattered. They stain with haematoxylin and near the tip of the head are grouped into three areas. They do not reach the brain. The vascular and nervous systems have been well described by previous authors. In the rhynchodaeum there are outpushings noted by Joubin and considered by him to connect the blood lacunae with the exterior. Although they protrude into the lacunae I have not been able to find any gap in the intervening tissue that would suggest free communication. These outpushings vary in number but have been seen in all types (Fig. 24).

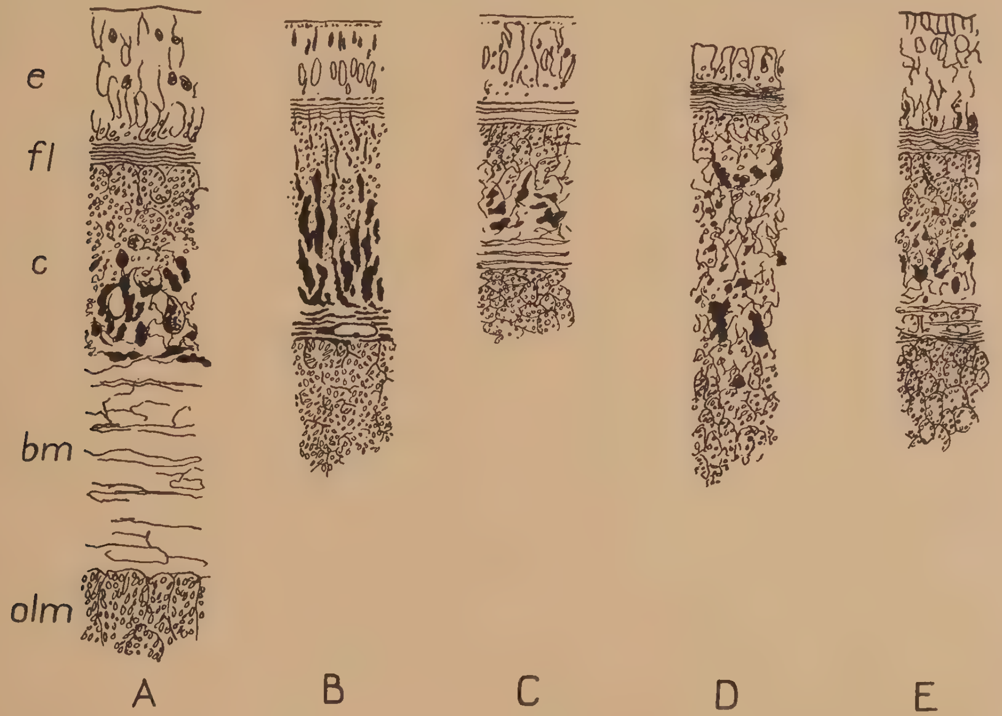

Fig. 26. *Lineus corrugatus*, McIntosh. The dorso-lateral epidermal layers in transverse section. Reference letters as in Fig. 25. *bm*, basement membrane; *c*, cutis; *e*, epithelium; *fl*, fibrous layer; *olm*, outer longitudinal muscles.

The divergences in the anatomy of the three types are connected with the relative position of the organs (Fig. 25) and in the gland cells of the cutis and the cutis itself. Fig. 26 shows the forms of the dorso-lateral cuticular layers at the level of the anterior end of the mouth. Type (i) possesses the thick muscle-free basement membrane of *Cerebratulus charcoti*, and of *C. corrugatus* as described by Bürger (1904, p. 96); type (iii) the thinner layer with circular fibres of *C. steinini*. A second series of type (i) shows the structure described in *C. validus*, Bürger. During the examination of the material by means of hand sections cleared in anilin oil it was generally found that the basement membrane conformed to type, but sometimes it did not. On cutting diagonal and longitudinal sections an explanation, based on the contraction of the muscles of the body, was found to cover the differences. When the body is contracted the cutis is thrown into circular wrinkles between which the basement membrane is compressed, giving the appearance of type (iii), while where the cutis bulges the type (i) cross-section occurs.

No eyespots could be seen on clearing in anilin oil. In the sections, however, a series of curious organs can be observed close to the cephalic slits (Fig. 27). These are spherical bodies that produced the granular appearance of the inside of the slits in the living animal. They may possibly have visual function although they appear very similar in structure to fibrous nerve tissue.

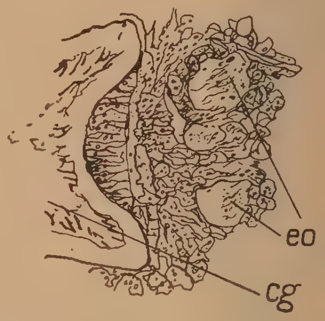

Fig. 27. *Lineus corrugatus*, McIntosh. Part of a transverse section of the head at the base of the cephalic slit, *cg*, to show the spherical granular bodies, *eo*.

I give below a list of the stations at which specimens were captured with the serial numbers of the specimens of which special investigation was made and sections cut. As I have remarked this species is common in the area and a large number of specimens not included in the list below were taken from King Edward Cove and also from Port Stanley Harbour, Falkland Islands, under stones at low tide.

List of stations at which *Lineus corrugatus* was taken. The dates, positions and depths of these stations will be found in the list of stations on pp. 220–5.

Station	Gear	No. of specimens	Serial number	Station	Gear	No. of specimens	Serial number
St. 39	OTL	18	—	St. WS 73	OTC	6	N 128
St. 45	OTL	4	N 134	St. WS 77	OTC	2	N 88, N 89
St. 51	OTL	16	N 126	St. WS 79	OTC	1	N 124
St. 53	RM	8	N 132	St. WS 80	OTC	1	—
St. 123	OTL	1	—	St. WS 84	OTC	4	—
St. 160	DLH	1	N 71	St. WS 88	OTC	2	N 133
St. 163	BTS	1	—	St. WS 225	OTC	2	N 61, N 95
St. 164	BTS	1	—	St. WS 228	OTC	1	N 55
St. 167	N 7–T	3	N 101		NCS–T N 4–T	2	N 113, N 86
	N 4–T	5	—				
St. 173	BTS	2	—	St. WS 237	NCS–T	2	N 74, N 51
St. 186	DLH	1	—	St. WS 246	OTC	1	—
St. 195	OTM	1	—	St. WS 248	OTC	1	—
St. WS 25	BTS	42	—	St. WS 249	DLH	2	N 66, N 67
St. WS 56	NH	3	—	St. MS 68	NRL	1	—
St. WS 62	BTS	6	—				

Lineus longifissus (Hubrecht).

Cerebratulus longifissus, Hubrecht, 1887.

One hundred and thirty-four fragments including eleven heads and four tails were preserved at St. 167 (N 81, N 81*a*). Fourteen complete worms were examined later. They had been caught in another net at the same station.

Two worms were reconstructed from reddish backed fragments giving approximate lengths of 7·0 cm. The breadth and depth were 0·7 and 0·35 cm. respectively.

The colour of the spirit specimens is reddish or greyish on the back and pale grey or white beneath. The body is flattened, anterior end more cylindrical than posterior, and the tail is pointed. The surface of the skin shows slight circular wrinkling especially anteriorly. As remarked by Hubrecht the mouth is small and the cephalic slits very long. They become shallower gradually, but appear much more sharply cut than in other Lineids. The following measurements were made of complete worms and fragmented heads.

Length of fragment from tip of head cm.	Greatest breadth cm.	Length of cephalic slits cm.	Length of mouth cm.	Distance from tip of head to anterior end of mouth cm.
3·9	0·45	2·1	0·225	0·55
3·3	0·625	2·7	0·20	0·65
2·55	0·5	1·9	0·05	0·45
3·5	0·6	2·05	0·15	0·7
3·5	0·5	1·8	0·05	0·45
4·1	0·45	1·65	0·06	0·6
Complete worm				
5·8	0·43	1·6	0·1	0·4
5·25	0·45	1·6	0·07	0·5

I can add the following notes to the account given by Hubrecht. Frontal organs are present. Head glands are diffuse, stain with haematoxylin and do not reach the anterior end of the brain. The small cephalic canals pass from the fissures just after the level of the ventral commissure. Before they penetrate the brain a dorsal branch is given off by the dorsal ganglion. This branch is extremely short. The posterior lobes of the brain lie in a blood sinus.

One of the characters of the species is the very marked power of autotomy.

Lineus roseocephalus, n.sp. (Plate XVI, fig. 24).

With the dark brown *L. corrugatus* collected under stones in the harbour of Port Stanley, Falkland Islands, was this light red form represented by a single specimen (N 22) 45·0 mm. long and about 1·0 mm. in diameter. In addition to the colour, differences from *L. corrugatus* were readily perceptible in the tapering shape of the body and the rounded anterior end. No mouth was visible but the cephalic slits were very long. The tip of the head was brown and the anterior end of the body was of a more crimson tint than the body farther back.

Anatomically the worm is very closely allied to *L. corrugatus*. The "eyes" are not present, however, and the mouth is very small.

Genus **Cerebratulus**, Renier

Cerebratulus larseni, n.sp. (Plate XVI, fig. 8; Fig. 28).

One specimen, somewhat damaged at the posterior end, was taken at St. 140 in 122–136 m. The length was 2·3 cm., breadth 0·14 cm.

The body is round in section but the head is flat. In outline from above it takes the form of an elongated lozenge. The mouth is a small longitudinal slit with swollen lips just behind the pinkish blotch on the head. The colour is pale yellow with a bright pink vague patch on the head and a pink line showing down each side of the body. A caudal appendage is present.

In spirit the specimen had broken up. The colour was bleached.

The head is rectangular in the early sections. The vascular and nervous systems conform to type but the upper branch of the dorsal ganglion is stout and short. It is separated at its distal end from the rest of the ganglion (Fig. 28). The longitudinal muscle layer of the body is strongly developed. The cutis is thin in comparison with the same layer in *Lineus corrugatus*. The basement layer is as thick as the subepithelial muscle layer.

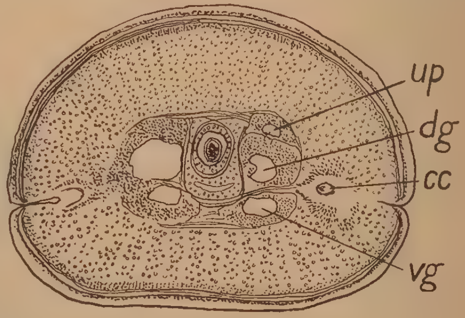

Fig. 28. *Cerebratulus larseni*, n.sp. Transverse section of the head in the posterior brain region. *cc*, cerebral canal; *dg*, dorsal ganglion; *up*, upper branch of the dorsal ganglion; *vg*, ventral ganglion.

I have named this species after Captain C. A. Larsen, the pioneer of whaling in the South Atlantic.

Cerebratulus malvini, n.sp. (Figs. 29, 30).

Certain of the Heteronemerteans from the area around the Falkland Islands possessed a caudal appendage. These worms were not sketched or noted in life so that the colour remains unknown. As far as one can judge from specimens in alcohol (N 52, N 65, N 72, N 97, N 100) the colour is very dark brown, darker on the back than the underside. No trace of markings remain. The lengths and breadths of four specimens are as follows: 36·0, 3·5 mm.; 11·0, 1·0 mm.; 55·0, 2·0 mm.; 45·0, 3·5 mm.

The cephalic slits are long and the mouth is very small. In one specimen (N 52) the caudal appendage was double (Fig. 29B). Apart from the absence of "eyes" there appears to be no feature by which one can distinguish the sections of these worms from

Lineus corrugatus. The cephalic slits are wider and larger altogether (Fig. 30), and this, with the absence of "eyes" and presence of a caudal appendage characterize the species.

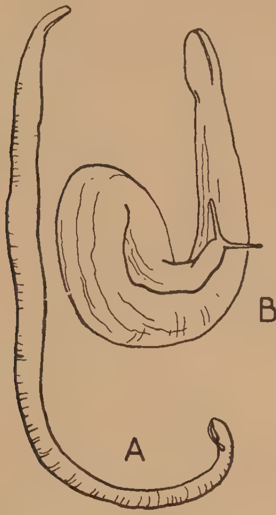

Fig. 29. *Cerebratulus malvini*, n.sp. A, B, outline sketches of preserved specimens.

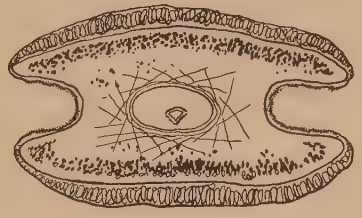

Fig. 30. *Cerebratulus malvini*, n.sp. Transverse section of the head near the tip showing the wide cephalic slits.

The specimens were taken at the following WS stations: 73 (N 52), 228 (N 100), 239 (N 72), 246 (N 97), 249 (N 65).

Order HOPLONEMERTEA

Genus **Amphiporus**, Ehrenberg

Amphiporus falklandicus, n.sp. (Fig. 36 D).

This species is represented by a number of specimens. It is closely related anatomically to *A. gerlachei*, Bürger and *A. lecointei*, Bürger. I have separated them on the following grounds: the colour in life from a single colour note; the size and shape of the preserved specimens and the position of the junction of the oesophagus and stomach with relation to the brain.

The station numbers and details of gear and depth, with the length, breadth and serial numbers of the specimens are given in the table below:

St.	Date	Gear	Depth m.	Length mm.	Breadth mm.	Serial no.
WS 84	24. iii. 27	OTC	75–74	—	—	—
WS 97	18. iv. 27	OTC	146–145	55·0	3·3	N 122
WS 225	9. vi. 28	OTC	162–161	48·0	2·5	N 62
				36·0	4·0	N 96
WS 228	30. vi. 28	OTC	229–236	47·0	4·8	N 84
				40·0	4·0	N 85
				36·0	2·5	—
WS 246	19. vii. 28	OTC	267–208	11·0	2·0	N 98
WS 248	20. vii. 28	OTC	210–242	—	—	—

The body is more elongated and slender than that of *A. gerlachei*, though the posterior end of the body is flattened as in this species (Fig. 36D). The anatomy is similar except that the oesophagus does not open into the stomach until after the brain. This is similar to *A. lecointei*, but from this form *A. falklandicus* differs in colour and shape. There are twelve nerves in the proboscis and an accessory armature of two reservoirs with from two to six stylets. Head glands and cerebral subepithelial glands are present and the cerebral organs persist behind the dorsal ganglia.

Male and female specimens were included in the collection and the ova of the latter contained the "paranucleus" remarked upon by Hubrecht in *A. marioni*.

Amphiporus gerlachei, Bürger, 1904 *a* (Figs. 31, 36C).

This species appears to be fairly common, though it was not captured in King Edward Cove and no sketch was made of the living animal. From a colour note and three series of sections I have identified it with *A. gerlachei*, Bürger. Seventeen specimens taken from the base of a large hollow sponge at St. WS 225 were noted as "bright pink" in life (N 94).

The lengths and breadths of preserved specimens were: 35·0, 6·0 mm. (N 63); 35·0, 5·5 mm. (N 64); 30·0, 7·0 mm. (N 94); 40·0, 7·0 mm.; 50·0, 7·0 mm.

The anterior end is cylindrical, the posterior very flat (Fig. 36C). The oesophagus opens into the stomach in front of the brain (Fig. 31). In other ways the anatomy corresponds to that of *A. lecointei*. There are twelve nerves in the proboscis, and the accessory armature consists of two reservoirs with from two to five stylets. The sex was determined in one specimen only—a male.

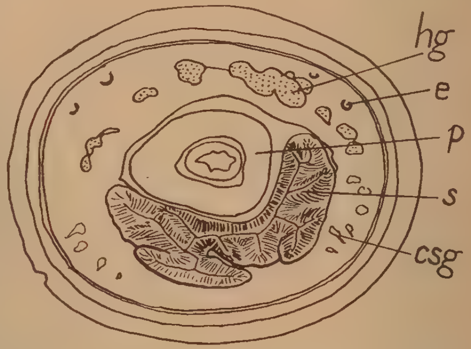

Fig. 31. *Amphiporus gerlachei*, Bürger. Transverse section of the head in front of the brain. *csg*, cerebral subepithelial glands; *e*, eyespot; *hg*, head glands; *p*, proboscis; *s*, stomach.

A. gerlachei was taken at the following WS stations:

WS 225. 9. vi. 28. OTC, 162–161 m. (N 94).
WS 246. 19. vii. 28. OTC, 267–208 m.
WS 249. 20. vii. 28. DLH, 166 m. (N 63, N 64).

Amphiporus inexpectatus, n.sp. (Fig. 32).

This species is represented by serial sections of a single specimen (N 108) taken at St. WS 231 off the Falkland Islands and not noted in life. The preserved specimen was 16·0 mm. long and 2·0 mm. in diameter, round in section and bleached of all colour. The proboscis was protruded but no armature could be made out after clearing.

Anatomy. The head glands open at the tip of the head above the proboscis pore. They form a thick strand close to the rhynchocoel and do not stain with haematoxylin (Fig. 32). They disappear before the brain. The epithelium at the level of the posterior end of the stomach is about twice as thick as the basement layer which is considerably thicker than the circular muscle layer. The longitudinal muscles are well developed.

There appears to be no distinction between oesophagus and stomach. A large folded tube passes through the region of the brain and opens by a frilled mouth under the proboscis pore. The tube enlarges slightly posteriorly. Branches of the anterior caecum reach the brain.

The proboscis possesses thirteen nerves and is stout and muscular. There is no dorsal strand in the lateral nerves. The cerebral organs are small and only just reach the brain. Their short canals open ventro-laterally. There are about fifteen eyespots on each side. The specimen was a male with immature testes.

I have separated this worm from the other Amphiporids on the nerves in the proboscis and the position and size of the cerebral organs.

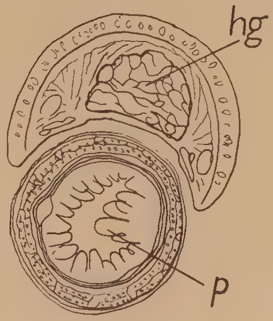

Fig. 32. *Amphiporus inexpectatus*, n.sp. Transverse section at the extreme tip of the head with the protruded proboscis, *p*. *hg*, head glands.

Amphiporus lecointei, Bürger, 1904 *a* (Plate XVI, fig. 9; Figs. 33–35, 36 B).

This species was taken at the following stations:

St. 27. 15. iii. 26. DL, 110 m. 1 (N 114).
St. 140. 23. xii. 26. OTL, 122–136 m. 4 (N 45).
St. 156. 20. i. 27. DLH, 200–236 m. 2.
St. 158. 21. i. 27. DLH, 401 m. 2.
St. 159. 21. i. 27. DLH, 160 m. 4.
St. 195. 30. iii. 27. OTM, 391 m. 2.
St. WS 25. 17. xii. 26. BTS, 18–27 m. 2 (N 120).
St. WS 93. 9. iv. 27. N 7–T, 133–130 m. 6 (N 125).
St. MS 71. 9. iii. 26. NCS–T, 110–60 m. 1 (N 115).

One specimen (N 45) was examined and sketched in life and afterwards sectioned. This, though similar in many respects to *A. michaelseni*, Bürger, has been separated from it by reason of the cerebral organs, armature and the number of nerves in the proboscis. It has been identified with *A. lecointei*, Bürger, on the shape, head glands, brain and cerebral organs. Much should have been added to make the original description adequate, for there is great similarity in the anatomy of the closely related species *lecointei*, *gerlachei*, *falklandicus* and *marioni*.

The length was 20 mm. and breadth 2·3 mm. A specimen sketched by Mr D. D. John at St. 156 was 23 mm. long.

Form and colour in life. The size and shape is remarkably uniform. The body is stout, almost circular in cross-section, bluntly pointed at the head and tapering to the tail. The head is marked off from the body by a transverse groove deep ventrally and incomplete dorsally. At each side the groove takes the shape of a backwardly directed V, and from it ventrally there are several furrows passing forward upon the head (Fig. 33B). The opening of the head gland can sometimes be seen at the tip of the head: the larger opening of the rhynchodaeum is subterminal.

There is a semi-lunar group of about twenty deeply embedded eyespots showing palely through the skin passing outwards on each side from the tip of the head along the margin and turning medially. Following these eyespots there is a deep closely-set posterior group of eyes behind the cephalic furrow of each side (Fig. 33A).

The distinctive marking of the species is a broad brownish red band down the back extending on to the head. The edges of the body and the underside are uncoloured.

Form and colour of preserved specimens. The stout body does not twist much. Often the ventral side is more convex than the dorsal and there is a tendency for the body to curl with the dorsal surface inside. Occasionally the ventral surface is flat or concave while the dorsal is humped. The proboscis is usually protruded. It is nearly the same length as the body. The colour can in some specimens be traced as a grey band. The eyespots are large. On clearing, the anterior group can be seen to consist of 10–20 on each side opening forward, the posterior of 16–18 opening laterally or posteriorly.

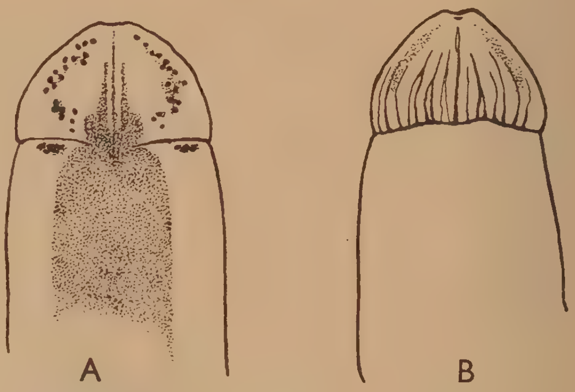

Fig. 33. *Amphiporus lecointei*, Bürger. A, dorsal, and B, ventral sides of the head.

Anatomy. The basement membrane stains somewhat with haematoxylin and is nearly as thick as the epithelium, which is itself very thick. Each of these layers is four to five times as thick as the circular muscles. The longitudinal muscles are thick and show a marked pennate arrangement of the bundles (cf. *A. marioni*, Hubrecht). There are subepithelial glands in the head confined to lateral tracts from the tip to just beyond the cerebral canals. These I propose to call cerebral subepithelial glands. They differ in appearance and staining reaction from the head glands and their ducts can be seen traversing the body layers direct to the exterior (Fig. 34). The head glands just reach the brain. They are compact strands opening by a median pore at the tip of the head.

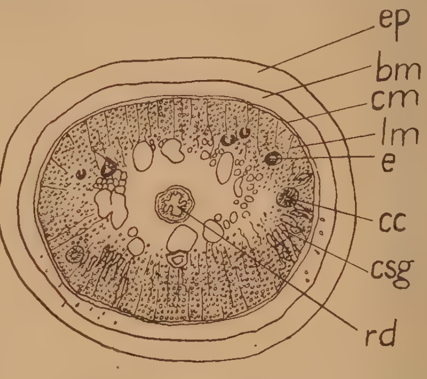

Fig. 34. *Amphiporus lecointei*, Bürger. Transverse section of the tip of the head. *bm*, basement layer; *cc*, cerebral canal; *cm*, circular muscle layer; *csg*, cerebral subepithelial glands; *e*, eye; *ep*, epithelium; *lm*, longitudinal muscle layer; *rd*, rhynchodaeum.

The proboscis is thin and is attached at about half the length of the body, but the rhynchocoel extends to the tail. The proboscis has twelve nerves. The armature consists of a main stylet on a base not longer than itself and two reservoirs, each with from four to seven stylets.

The relative positions of the stomach, excretory organs and branches of the anterior caecum are believed to vary with the degree of contraction of the body. Thus in one series of sections the stomach wall is visible some distance before the brain, showing that the alimentary canal has the power of independent movement and that not much reliance can be placed in distinguishing characters based on position. The anterior caecum has branches which are first seen close behind the excretory tubules (Fig. 35).

The vascular system consists of two lateral vessels forming a head loop and passing one on each side of the rhynchocoel through the brain region. They unite with a dorsal vessel by a transverse connection and pass down the body ventral to the nerves.

There is a convoluted excretory tubule on each side close behind the cerebral organ, lying above the nerve and opening to the exterior by a single dorso-lateral duct.

The brain is of good size. The dorsal ganglia are larger than the ventral and lie immediately over them. At the posterior end of the ventral ganglia there may be a con-

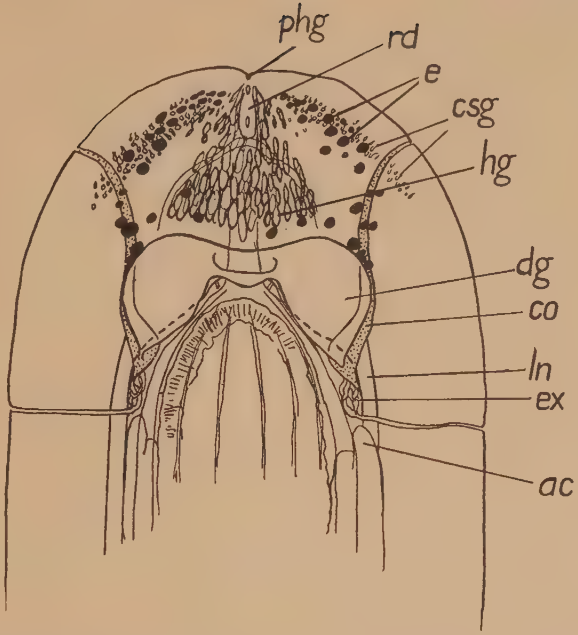

Fig. 35. *Amphiporus lecointei*, Bürger. Diagram from a graphic reconstruction of the head and anterior end of the body to show the relations of the brain, cerebral organs, excretory and alimentary systems. *ac*, anterior caecum; *co*, cerebral organ; *csg*, cerebral subepithelial glands; *dg*, dorsal ganglion; *e*, eyespots; *ex*, excretory tubule; *hg*, head glands; *ln*, lateral nerve; *phg*, opening of the head gland; *rd*, rhynchodaeum.

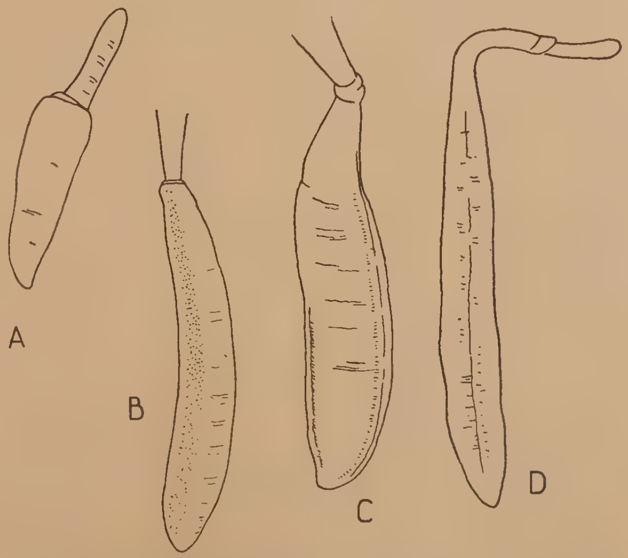

Fig. 36. Outline drawings (× 3 approx.) of *Amphiporus marioni* (A), *A. lecointei* (B), *A. gerlachei* (C), and *A. falklandicus* (D).

traction twist when they become the lateral nerves. No dorsal strand could be detected in the lateral nerves. The cerebral canals are short. Their openings are ventro-lateral. The organs themselves are large and at first closely applied to the sides of the dorsal ganglia. Fibres from the ganglia pass into them and form the only connection. They shift ventrally, wedging themselves between the dorsal and ventral ganglia. On the disappearance of the dorsal ganglia the organs also diminish and end. Fig. 35 shows the relative positions of the various organs in the head from a graphic reconstruction. Reference to Fig. 37 will show how closely the main anatomical features of this species resemble those of *A. marioni*, allowing for the greater degree of contraction in the latter and the fact that the proboscis is considerably thicker. In Fig. 36 outline drawings of spirit specimens of the four species are given illustrating the differences in shape of the body. *A. lecointei* should be easily recognized in life by its distinctive form and colour.

Amphiporus marioni, Hubrecht, 1887 (Figs. 36 A, 37, 38).

One specimen (N 5) was taken from a kelp root from King Edward Cove. It was not sketched until the following day when it was sorted from *A. moseleyi* with which it had been fixed. The colour and general appearance are probably very similar. The length was 9·3 mm., the breadth 1·5 mm. (in spirit).

The small stoutly built body is flattened posteriorly. No eyes can be seen (Fig. 36A).

Anatomy. In the region of the stomach the longitudinal muscle layer is three or four times as thick as the epithelium. Farther back down the body it is less than twice as thick and in some positions—mid-ventrally under the gut and mid-dorsally—it is thinner than the epithelium. The basement membrane is very thick and appears fibrous.

The head glands are large and compact. One strand, dorsal to the rhynchocoel, opens by a pore ventral to the tip of the snout. This strand does not reach the dorsal commissure. There are two lateral strands, one on each side of the rhynchocoel, which extend back ventral to the brain as far as the ventral commissure and opening of the cerebral canals (Fig. 37). There are cerebral subepithelial glands on each side from the tip of the head to the cerebral organs. About fifteen eyespots with very light brown pigment are present on each side.

The oesophagus opens into the rhynchodaeum before the brain and at the level of the cerebral organs it becomes the stomach. The anterior caecum is much branched and the branches extend forwards and approach the posterior end of the brain. The lateral diverticula of the gut extend above the lateral nerves (Fig. 38). The proboscis is thick. There are fifteen nerves. The armature consists of a main stylet

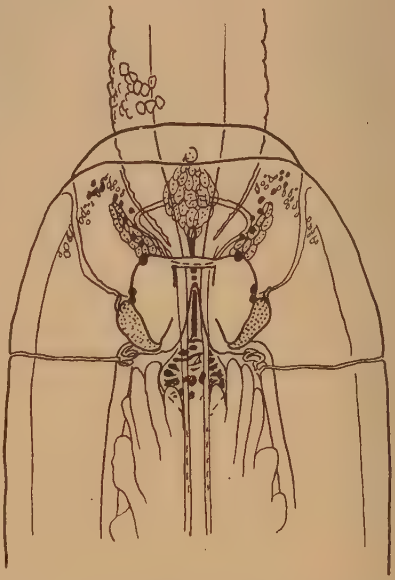

Fig. 37. *Amphiporus marioni*, Hubrecht. Graphic reconstruction of the anterior end of the body.

and two accessory stylet reservoirs with one or two complete stylets and a number of fragments. The rhynchocoel extends to the posterior end of the body. The vascular and excretory systems are similar to those of *A. lecointei.*

The brain is small. The dorsal ganglia are considerably larger than the ventral and lie immediately over them. At the posterior end of the ventral ganglia the lateral nerves are given off sharply at right angles to the long axis of the body (Fig. 37). They appear to double upon themselves again just after turning down the body. The twists are vertical, instead of lateral as described in *A. moseleyi*, and are plainly the effects of contraction. The cerebral canals are short. Their openings are ventral and lateral into a deep circular groove near the tip of the head. The organs themselves are large and closely applied to the sides of the dorsal ganglia, but posteriorly they push between dorsal and ventral ganglia and extend back beyond the former.

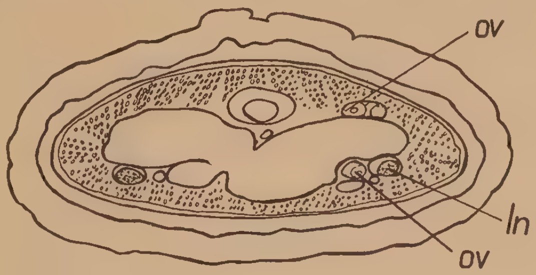

Fig. 38. *Amphiporus marioni*, Hubrecht. Transverse section of the body at about half its length. *ln*, lateral nerve; *ov*, gonad.

The generative sacs (female) are both dorsal and ventral to the gut branches and the nuclei of the ova contain a deeply staining nucleolus. The "paranuclei", as described by Hubrecht (1887), are present.

The features that have caused a distinction to be made between this species and *A. gerlachei*, Bürger, which it closely resembles when preserved, are the number of nerves in the proboscis and the colour. A reddish worm would undoubtedly have been separated from the specimens of *A. moseleyi* on capture.

Amphiporus moseleyi, Hubrecht, 1887 (Plate XVI, figs. 3, 18; Fig. 39).

Amphiporus Racovitzai, Bürger, 1904 *a*.

This species (N 4) was very common in King Edward Cove and round the coast of South Georgia. Almost every kelp root sheltered one or more specimens, and a considerable range in colour and size was observed. The largest specimen was 10·2 cm. long and 12·0 mm. broad. Specimens were also taken at the following stations:

St. 123. 15. xii. 26. OTL, 230–250 m.
St. WS 219. 3. vi. 28. NCS–T, 116–114 m. (N 79).
St. MS 67. 28. ii. 26. BTS, 38 m.

Form and colour in life. The usual length is 5–6 cm. and the breadth 7–8 mm. The body is stoutly built and considerably flattened. The ventral surface is flat and forms a broad "sole". The dorsal surface is convex, especially anteriorly where a longitudinal hump marks the presence of the muscular proboscis. There is no distinction of head from body, but the head end is rather less blunt than the tail. In outline the body resembles a willow leaf. No cephalic slits or eyespots are visible. The opening of the proboscis pore is just ventral to the tip of the snout. The colour is blue-green, yellow-green, pale buff or light brown on the back, while the underside is always pale buff. The colour is deepest in individual worms on the hump caused by the proboscis. Occasionally a reddish tinge marks the position of the ganglia and a narrow whitish stripe at the margin of the body anteriorly the lateral glands.

Form and colour of preserved specimens. After anaesthetization in chloral hydrate very little contraction appears to take place on fixing. The green colour is retained in spirit specimens for many months. The body does not change in shape but contraction causes two grooves to appear, one near the tip of the head, the other a little farther back. When only slightly marked these grooves take the form of two pairs of short lateral vertical furrows. Two irregular groups of very small eyespots—up to sixty—can be seen when the head has been cleared in anilin oil. The eversible part of the proboscis is apple green in colour.

The anatomy of this species has been described by Hubrecht (1887) and Bürger (1904 *a*, 1907). Variations occur in the following details. The eyespots, though always very small, vary considerably in number, and the pigment granules which they contain are of a deep green-blue colour.

The lateral glands (very strongly developed cerebral subepithelial gland cells) stain deeply with haematoxylin; the head glands less deeply. The number of nerves in the proboscis may be from eleven to sixteen though the usual number is fourteen. The base of the main stylet may be brown or green and there is a belt of brown gland cells round the armature. The base of the main stylet is less than twice as long as the stylet itself. The brain and cerebral organs are shown in Fig. 39. As noted by Bürger (1907 (1912), p. 173) the dorsal ganglia lie laterally rather than dorsally to the ventral. They are, as it were, pressed forwards and outwards so that they are in almost the same plane as the ventral ganglia. In consequence the dorsal commissure is very long. The double twist in the lateral nerves is probably the result of contraction. The cerebral organs, consisting of a narrow canal ensheathed by eosinophile tissue on each side, extend a short way beneath the dorsal ganglia but do not penetrate them.

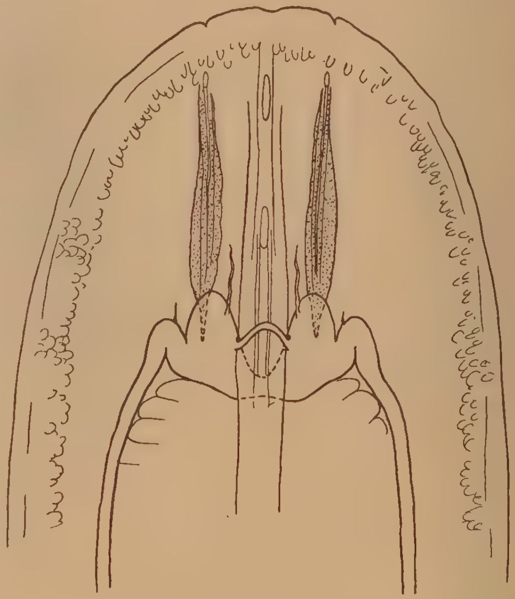

Fig. 39. *Amphiporus moseleyi*, Hubrecht. Diagram of the anterior end of the body showing the brain, cerebral organs, cerebral subepithelial glands and the position of the opening of the rhynchodaeum and the opening of the oesophagus into it.

Amphiporus schollaerti, n.sp. (Figs. 40, 41).

A single specimen (N 58) of a large worm was taken at St. 182 in the Schollaert Channel, Palmer Archipelago. The colour as noted in life was pale buff. The preserved specimen was 97 mm. long, and 5·0 mm. broad. It was almost round in section from one end to the other except the head which was blunt and flat (Fig. 40). There was a pore visible at the tip and a larger aperture just ventral to this. Lateral vertical grooves were also present, joining ventrally. The body was slightly dusky at the sides but otherwise colourless.

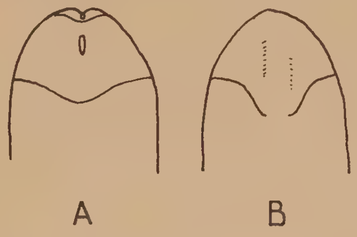

Fig. 40. *Amphiporus schollaerti*, n.sp. A, ventral surface of head of preserved specimen; B, dorsal surface.

The anatomy is similar to *A. lecointei* with the exception of the proboscis which has fourteen nerves. Head glands, cerebral subepithelial glands are present and the cerebral organs occupy a position between the ganglia and extend behind the dorsal ganglia (Fig. 41).

The excretory tubules are large and the anterior caecum has forward branches but they are far behind the brain.

I have separated this worm from the other Amphiporids on its size, colour and innervation of the proboscis. The armature was not seen. The specimen was male.

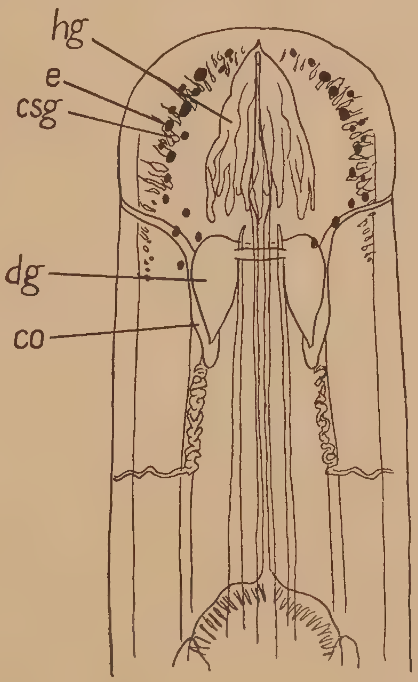

Fig. 41. *Amphiporus schollaerti*, n.sp. Diagram showing the organs at the anterior end of the body. From a graphic reconstruction. *co*, cerebral organ; *csg*, cerebral subepithelial glands; *dg*, dorsal ganglion; *e*, eye; *hg*, head gland.

Amphiporus scoresbyi, n.sp. (Figs. 42, 43).

Three specimens of this small distinctively shaped species were obtained at St. WS 302 (N 77), the colour note being "orange-yellow to orange-red dorsally and ventrally with very pale yellow periphery and proboscis. Darker pigment in mid-line posteriorly". Two specimens were taken at St. WS 548 and one at St. WS 550. These were of the same size and shape. They had been preserved in formalin and all colour was bleached.

Form and colour of preserved specimens. The body is fusiform, the length 5·5 mm., diameter of the mid-body 2·0 mm. Its surface is thrown into small rounded eminences which at the anterior end form three or four rows of short fimbriae (Fig. 42). The colour is uniformly yellowish with no sign of eyes or markings.

Anatomy. The head glands open at the tip of the head just before the proboscis pore. The glands stain deeply with haematoxylin. The thin strands disappear before the brain, but anteriorly they fill the head. The oesophagus joins the rhynchodaeum very close to the external opening and is from this point lined with the deeply staining cells characteristic of the stomach. Its walls are folded (Fig. 43). I could see no eyespots in the cleared specimens nor were any evident in the sections. There are no cerebral subepithelial glands, but there are cutis glands in the longitudinal muscles.

The basement layer is very thick and stains lightly. The epithelium in all the specimens is much wrinkled but apparently it is not much thicker than the basement membrane. The circular muscles are less than half as thick. The longitudinal layer is well developed but does not show the pennate arrangement of bundles so noticeable in *A. marioni* and other species. The proboscis is stout. It has twelve nerves and the accessory armature consists of two reservoirs each with two or three stylets. The main stylet could not be seen.

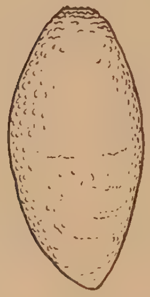

Fig. 42. *Amphiporus scoresbyi*, n.sp. Sketch of a preserved specimen. × 8 approx.

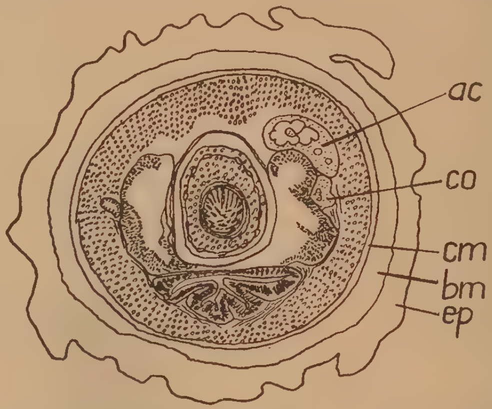

Fig. 43. *Amphiporus scoresbyi*, n.sp. Section, slightly oblique, across the brain region. *ac*, lateral branch of the anterior caecum; *bm*, basement layer; *cm*, circular muscle layer; *co*, cerebral organ; *ep*, epithelium.

Two lateral branches of the anterior caecum extend forward and end above the brain (Fig. 43). The excretory tubules, as usual, lie between the cerebral organs and the branches of the anterior caecum. The efferent duct is continued back above the lateral nerve and opens laterally much nearer the tail than the head.

The brain is of fair size, both ganglia being nearly equal. The cerebral organs open by a fine canal laterally and run in towards the brain obliquely back. The organs wedge themselves between the ganglia and protrude posteriorly beyond the dorsal ganglia with which they have nervous connections. The lateral nerves are not much flattened in the body. They join above the anus.

The sex of the sectioned specimen could not be determined.

Amphiporus spinosus, Bürger, 1893 (Plate XVI, fig. 22; Figs. 44, 45).

A. spinosissimus, Bürger, 1893; *A. cruciatus*, Bürger, 1893; *A. multihastatus*, Joubin, 1914.

This species could nearly always be found in kelp roots. Three types were originally described under N 3, N 16, N 20, the different sizes, number of eyespots, colour and states of contraction leading to confusion. The length and breadth vary from 25 and 0·8 mm. to 180 and 2·8 mm., though the majority are shorter and broader than the latter.

The body is round, tapering at the posterior end. The snout is broadly acute. There may be no distinction between head and body, or the head may be broader than the broadest part of the body (in the smaller specimens) and two partial lateral furrows may be present, almost vertical in direction, with a chevron groove behind the head. This groove is complete ventrally. Sometimes the aperture of the rhynchodaeum can be seen. The colour is pale pink, pinkish red, brick red, orange or light orange red, usually deeper on the back and anteriorly. Sometimes the underside of the body is much paler than the back. There are two groups of eyespots on each side, often appearing as vague blackish patches.

Form and colour of preserved specimens. The lengths and breadths of a number of specimens are as follows: 51·0, 5·0 mm.; 31·0, 3·2 mm.; 60·0, 4·5 mm.; 85·0, 4·5 mm.; 14·0, 1·8 mm.; 32·0, 1·8 mm.; 130·0, 3·5 mm.

The body is round in section, the head blunt and the tail acute. The head is usually marked off from the body by a distinct and almost complete annular groove; dorsally this groove forms a wide V with the apex pointing back (Fig. 44). Anterior to this there are often lateral grooves, as in Fig. 44, and sometimes a median vertical groove in which can be seen the openings of the head gland and rhynchodaeum. The eyes are not all visible unless the specimen is cleared. On clearing two groups of brown cup-shaped eyespots can be determined on each side. The eyes vary from fifty or so in each group to small numbers like seven in the anterior and four in the posterior group of one side. They appear to increase with the size of the worm. The anterior eyes open forwards, the posterior more to the side, and they vary in size. The colour is usually bleached, but sometimes a faint general pinkish tinge is observed.

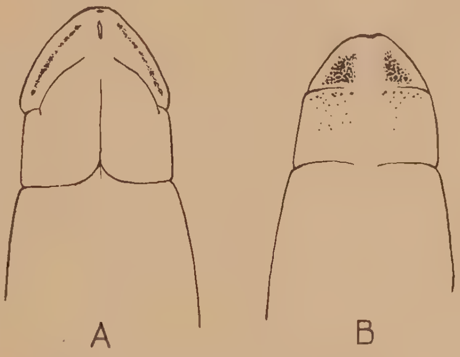

Fig. 44. *Amphiporus spinosus*, Bürger. A, ventral; and B, dorsal surface of head.

Anatomy. The head glands open at the tip of the head. There is a main compact dorsal strand which is joined by a smaller ventral strand under the vascular loop just anterior to the opening of the rhynchodaeum (Fig. 45A). The dorsal strand becomes thin and scattered posteriorly and does not extend to the brain. The ventral strand forms an investment to the rhynchodaeum on each side and continues back past the junction with the oesophagus. It, too, disappears before the brain.

The epithelium is very thick. In places it is thicker than basement membrane, circular muscles and longitudinal muscles put together. The basement membrane itself is thick and stains strongly. In the head, at about the level of the cerebral organs, there are eosinophile glands in the longitudinal layer whose ducts pass through the circular layer and basement membrane. These are not seen farther down the body.

The oesophagus is at first thin and small. It expands in the region of the brain into the stomach. Far back there is an anterior caecum with two short forward branches. The vascular system is normal and the excretory tubules occur just posterior to the brain.

The proboscis as far as the armature is almost half the length of the body. The accessory armature and proboscidial nerves vary greatly, though there is always a main stylet mounted on a brownish pear-shaped base (Fig. 45B). The following range of variation has been found:

Serial No.	Length of worm, mm.	Accessory reservoirs	Number of stylets in each reservoir	Number of nerves
N 16	60·0	18	1	—
N 16	90·0	18	1 (2)	14
N 20	14·0	7	1 (2) (3)	—
N 20	32·0	2	3	—
N 20	11·0	6	1	11
N 20	30·0	8	2 (3)	—
N 3	130·0	12	2 (3)	17
—	65·0	14	2 (3)	—
—	60·0	13	2 (1)	—
—	38·0	9	2 (1)	—
—	30·0	8	2 (3)	—
N 3	—	7	—	17
N 3	62·0	18	2 (1)	15
N 3	—	12	2 (1)	15
N 3	—	11	2	15
N 3	—	16	2 (1)	17
N 16	92·0	22	1 (2)	18
N 20	—	5	—	—
N 3	—	—	—	16
N 110	75·0	13	2 (1)	19
N 121	45·0	22	1	—
—	27·0	10	2 (1)	17
N 131	50·0	—	—	17
N 135	95·0	—	—	26
N 136	27·0	13	—	16

It seems evident that no specific value can be given either to the armature or to the proboscidial nerves. There is a possibility of increase with size or age.

The brain is fairly large but does not show any peculiarity. In one series of sections the lateral nerves left the brain by a sharp twist outwards, but this is merely the effect of contraction. The cerebral organs open by two very small pores ventro-laterally behind the opening of the rhynchodaeum. The organs are small and do not reach the brain.

Some of the specimens were males, some females. The gonads are shed laterally both above and below the nerves (Fig. 45D). Eggs were ripe in November and December.

In view of the extreme variation in the accessory armature and proboscis nerves the distinctions that have been drawn on these characters cannot hold. I therefore feel justified in bringing together the species described by Bürger and Joubin under *A. spinosus*, Bürger.

In addition to the collection from King Edward Cove this species was taken at the following stations:

St. 39. 25. iii. 26. OTL, 179–235 m.
St. 45. 6. iv. 26. OTL, 238–270 m.
St. 123. 15. xii. 26. OTL, 230–250 m.
St. 140. 23. xii. 26. OTL, 122–136 m.
St. WS 56. 14. i. 27. NH, 2 m.
St. WS 62. 19. i. 27. BTS, 26–83 m.
St. WS 65. 22. i. 27. Sh. coll.
St. WS 73. 6. iii. 27. OTC, 121–130 m.
St. MS 68. 2. iii. 26. NRL, 220–247 m.
St. MS 71. 9. iii. 26. BTS, 110–60 m.

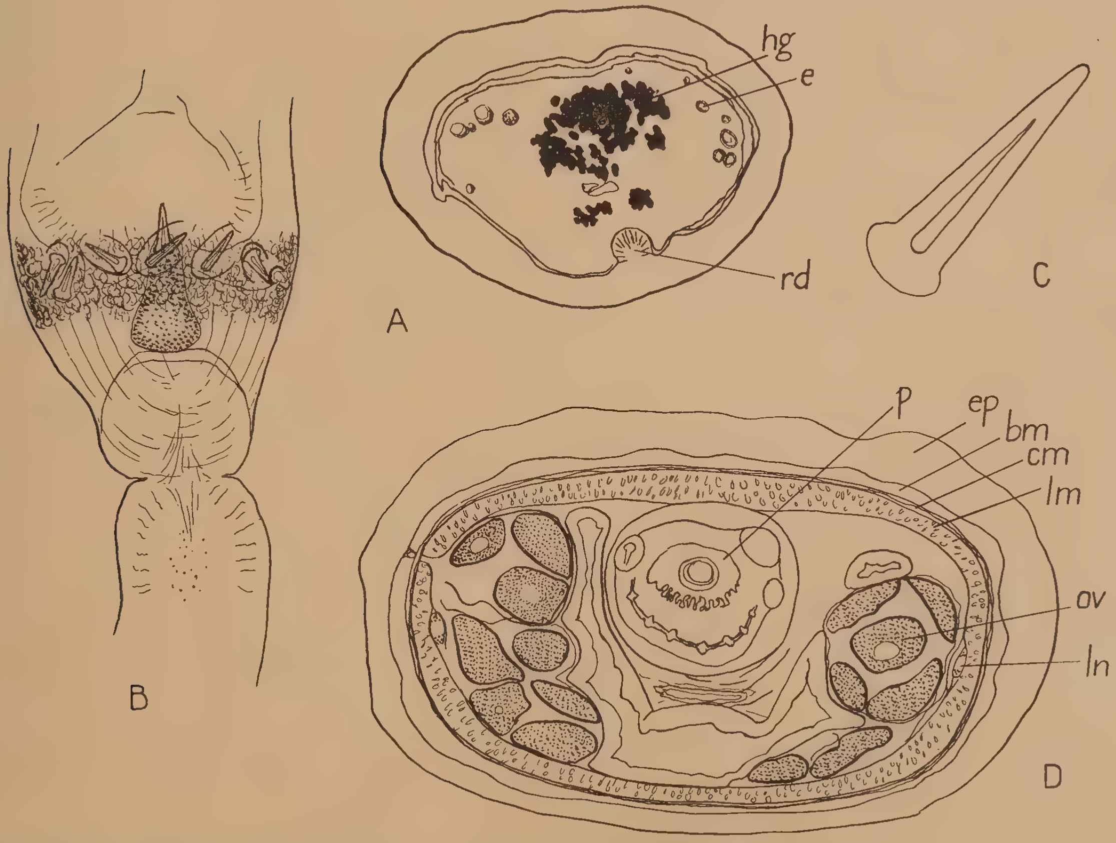

Fig. 45. *Amphiporus spinosus*, Bürger. A, section across the tip of the head; B, armature; C, accessory stylet; D, transverse section of the body. *bm*, basement membrane; *cm*, circular muscle layer; *e*, eye; *ep*, epithelium; *hg*, head gland; *lm*, longitudinal muscle layer; *ln*, lateral nerve; *ov*, gonad; *p*, proboscis; *rd*, rhynchodaeum.

Genus Tetrastemma, Ehrenberg

Tetrastemma esbenseni, n.sp. (Plate XVI, figs. 4, 23; Figs. 46, 47).

This species is not a common one. It occurred as follows:

7. iii. 26. King Edward Cove, South Georgia, 1 (N 18).
9. iii. 26. Maiviken, under stones, 7 (N 18).
St. 39. 25. iii. 26. OTL, 179–235 m. 2 (N 44); N 4–T, 20 (N 23, N 93, N 112).
St. 123. 15. xii. 26. OTL, 230–250 m. 1 (N 18).

The lengths and corresponding breadths were: 30·0, 0·7 mm.; 90·0, 0·8 mm.; 22·0, 0·7 mm.; 53·0, 1·3 mm.

The body is thin, soft and round in section, tapering at the head and tail. The head is pointed and there is no neck between it and the body. There is a chevron groove behind the head, complete ventrally. The eyespots are arranged in four groups at the corners of a rectangle, the number in each group varying from one to six, the anterior groups usually containing more than the posterior. The colour is light yellow or yellowish red. The gut can usually be seen through the body wall. In the specimens which were separated as N 44 the vascular system was more engorged than usual and no eyes were seen (Plate XVI, fig. 23), but they were identified with the other forms from the sections.

Form and colour of spirit specimens. The body is contracted and cylindrical (lengths 18 and 15 mm. with breadths of 1·4 and 1·0 mm.). All colour is bleached and no eyes are visible. On clearing in cedar oil one specimen possessed the usual two pairs of eyes imperfectly formed, another had four large eyes and several small perfect brown cup-shaped eyes close to them. Two more variations are shown in Fig. 46. The proboscis is always small and thin. The armature consists of a main stylet 0·065 mm. long on a base 0·083 mm. and a curiously irregular accessory armature. One specimen had two accessory reservoirs, one with five stylets and the other, which appeared to be double, with five and six stylets. Another specimen had three stylets in each of two reservoirs and yet another had five reservoirs crowded together on one side of the main stylet each with four or five. I could not determine the nerves in the proboscis.

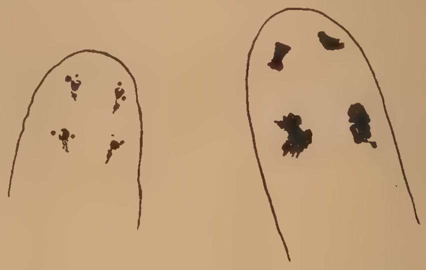
Fig. 46. *Tetrastemma esbenseni*, n.sp. Heads of two specimens cleared in cedar oil showing variation in eyespots.

Anatomy. The head glands open at a median ventral pit. They are very large, filling the head and persisting dorsally to the posterior end of the brain, ventrally farther back still.

The basement membrane is thick, nearly as thick as the epithelium. It does not stain. The circular muscle layer is about half as thick as the basement membrane and the longitudinal layer about as thick as the epithelium but thicker ventrally.

The vascular system is well developed on the usual plan, but the vessels are much dilated or very capacious and full of nucleated corpuscles. This appears to be a constant character of the species, though it does not always appear in life in the marked form shown in Plate XVI, fig. 23.

The cerebral organs are very small and far in front of the brain. The relative positions of the brain, cerebral organs, eyes and head glands can be seen in the graphic reconstruction (Fig. 47). The anterior caecum has no forward branches and lies far behind the brain. The brain is large, the dorsal ganglia being about equal in size to the ventral and continuing into the lateral nerves down the body.

I have not been able to identify this form with any known species although it approaches *T. belgicae*, Bürger, 1904*a*.

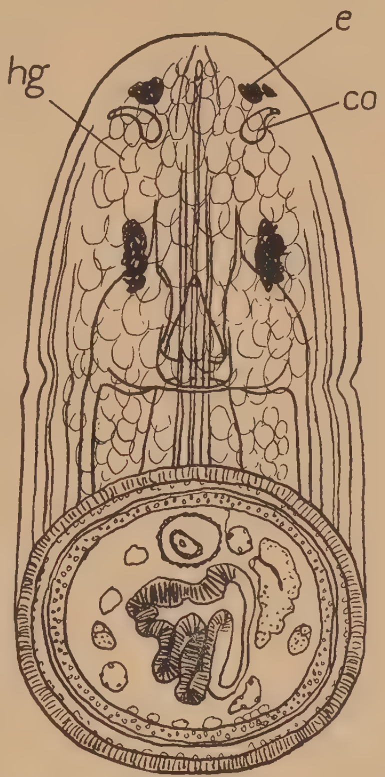

Fig. 47. *Tetrastemma esbenseni*, n.sp. Graphic reconstruction of the head and anterior end of the body. *co*, cerebral organ; *e*, anterior eye; *hg*, head glands.

Tetrastemma georgianum, Bürger, 1893 (Plate XVI, figs. 2, 13; Fig. 48).

This species was first noted from King Edward Cove. Two specimens were taken in September and four in October 1925, from kelp roots. A single specimen occurred at St. WS 65 in Undine Harbour. The smallest worm was 3·5 mm. long, but the usual length was from 10 to 15 mm., breadth 0·7 mm. The original sketch and description were made from six specimens (N 7). In 1929 a single specimen was collected in the dredge in King Edward Cove which was identified later with a larger form described under N 15, no differences being found in sections. The size attained may be 25·0 mm. Other captures were made—three specimens at St. 123, one at St. 140 and one at St. 51 (identified from sections, N 126).

Form and colour in life. The head is somewhat round in outline from above, but the snout has a median vertical cleft. The body is broadest at about half its length and is tubular and soft. The colour is brown, brownish red or mauve on the back, much paler beneath. With a low magnification (×10) the pigment appears granular. On the head the pigment band narrows and becomes defined so that the head appears to be bordered with white. On each side a white tag or strip passes up, while a little farther back the body colour is separated from that of the head by a fine white line which forms a wide V with the apex pointing back. I have never seen the anterior tags joined as a band. Four eyespots are present in two pairs. The first pair is situated at the anterior edge of the head pigment; the second lies within the white tags. A pair of vertical furrows which may be tinged with red can be seen in the tags.

Form and colour of preserved specimens. Length 9 and 13 mm., breadth 0·8 and

1·3 mm. respectively. The head is blunter than the tail and is marked off from the body by lateral opposite furrows and a complete circular chevron groove whose apex points back ventrally. No eyes are visible. The colour is usually bleached but may be yellowish.

Anatomy. The epithelium is thick. In one series of sections it was at the head almost twice as thick as the basement membrane, circular and longitudinal muscles together. Farther back on the body its relative thickness was less. I have some doubt of the value of comparative measurements of the epithelium and muscle layers, for another series shows a thick basement membrane not much stained, and a clear layer of circular muscles, the two together being about equal in thickness to the epithelium; it seems probable that bad fixation may be responsible for these differences.

The head gland is compact. It opens by a median pore at the tip of the head. There are three strands, one median dorsal and two lying laterally along the rhynchocoel. The former nearly reaches the dorsal commissure. The oesophagus opens into the rhynchodaeum near the snout and enlarges to the stomach just in advance of the brain. The anterior caecum sends forward two diverticula above the lateral nerves which overlap the posterior ends of the dorsal ganglia (Fig. 48), although the relative position of the branches and ganglia is altered by the state of contraction. The single excretory ducts open before the junction of the anterior caecum with the gut.

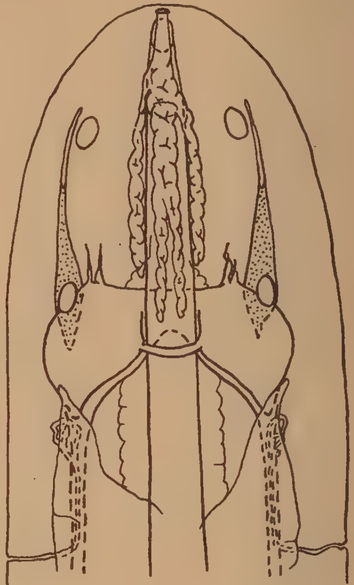

Fig. 48. *Tetrastemma georgianum*, Bürger. Graphic reconstruction of the head and anterior end of the body.

The proboscis is stout. The armature consists of a main stylet on a pear-shaped base larger than itself and two accessory reservoirs each with one or two stylets. There are ten nerves.

The ventral ganglia are a little larger than the dorsal. The cerebral canals appear as furrows on the ventral surface just in advance of the anterior pair of eyespots. They deepen and sink in. The organs join the dorsal ganglia from a ventro-lateral direction at the level of the ventral commissure (Fig. 48).

Tetrastemma gulliveri, Bürger, 1893 (Plate XVI, figs. 11, 17; Fig. 49).

This species was originally described and sketched at different times under the designations N 10 and N 14, but intermediate forms showed later that the differences lay in the size of the body and the distinctness of its markings. Subsequent investigation of the armature proved the identity. Thirty-four animals were examined in life, and from sections the following single specimen was sorted from the collection: St. 144, 5. i. 27, NCS–T, 155–178 m. (N 123). The lengths varied from 4 to 17 mm., the breadths from 0·6 to 1·6 mm.

Form and colour in life. The body is somewhat fusiform and in movement resembles *Oerstedia* in its semi-rigidity. The tail is more pointed than the head. Eyespots are visible in the smaller specimens. The colour is yellowish brown with a narrow median ventral pale "sole". The larger worms are darker and show less of the mottling—light irregular patches and dark spots—that is apparent in the smaller. There is a light ring circling the body at the back of the head, usually behind the second pair of eyespots but sometimes coincident with them. This pale annulation is characteristic of the species in life.

Form and colour of spirit specimens. Lengths 10 and 16 mm., breadths 0·7 and 1·4 mm. The body is nearly cylindrical, with the head thicker and blunter than the tail. There is sometimes a complete annular groove at the back of the head. The eyespots are not visible. The colour is usually completely bleached, but occasionally sufficient brown remains to display the white neck band. When cleared in anilin oil the pigment shows as black specks. The eyes, which are also rendered visible, are two pairs of brown cups, the concavity of the anterior pair being antero-lateral, that of the posterior pair postero-lateral. The eversible part of the proboscis is less than half the length of the body.

Anatomy. The epithelium is very thick. The relative thickness of the body layers can be seen in Fig. 49. The head glands fill the head completely and extend back on all sides of the brain. Posteriorly they end dorsally with the dorsal ganglia, but they continue beneath the stomach and anterior caecum until the two forward diverticula of the latter join it. The diverticula almost reach the brain. The proboscis is well developed and possesses ten nerves. The armature consists of a slim main stylet on a rounded base and two reservoirs each with four, five or six stylets.

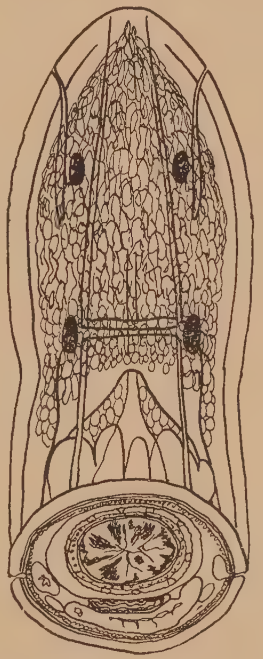

Fig. 49. *Tetrastemma gulliveri*, Bürger. Diagram from a graphic reconstruction of the head showing the eyes, brain, cerebral organs, and head glands.

The dorsal ganglia are small for the size of the brain and the commissure is thin. The lateral nerves pass outwards and up from the ventral ganglia and they each carry down the body a strand of fibres from the dorsal ganglion. The cerebral organs are very small and thin. They open laterally not far from the head-gland pore and consist of a tube sheathed with large gland cells extending a short distance behind the first pair of eyes. The excretory ducts open far after the brain.

The specimens taken in King Edward Cove in 1929 and 1930 came from a small red alga. Three of these were found in mucous tubes attached to the weed. In 1929 four brown worms within mucous tubes had been found attached to the rootlets of kelp and described as N 50. On sectioning they proved to be *Tetrastemma gulliveri*. The epithelium was torn off and the internal organs degenerated, especially the brain. The cerebral organs could be seen and the eyes and enormously developed head glands, though the latter did not stain as they had in the free specimens. The lateral nerves had degenerated considerably and the body consisted of a thin investment of basement membrane and muscles and a large amount of internal structureless substance in which the gut walls could still be recognized. No genital products could be seen. A specimen of *T. gulliveri* taken from red algae off the Point in King Edward Cove in March 1930 was full of eggs, so that there is evidence of a form of hibernation in this species.

Tetrastemma hansi, Bürger, 1893 (Plate XVI, figs. 6, 15; Fig. 50).

This species was first collected from the kelp roots in King Edward Cove in October 1925. Thirteen specimens were taken, sketched and noted (N 12). In March 1926 seven specimens differing in colour and body form were collected and described under N 17. These were later proved from their anatomy to be identical with the earlier forms. In April 1927 many specimens were collected of intermediate size and covering the range of colour. In November 1927 a specimen was taken that contained nearly ripe gonads visible through the ventral surface of the body.

Several small immature specimens were collected at St. 53 (Falkland Islands) and identified from sections (N 106).

Form and colour in life. The length and breadth rarely exceed 10·0 and 1·0 mm., though the breadth may be less for the same length. The body is round; the head just visibly marked from the body by its greater width. There are two lateral grooves on each side of the head and two pairs of eyespots. The head tapers to an acute snout. The colour varies from very light brown through shades of yellow-brown to light red and pink. There are sometimes traces of a pale median line down the back, not visible near the head and fading before the tail. Ventrally the animals are pale.

Form and colour of preserved specimens. The body is round in section, about 8 mm. long and 0·5 mm. broad. The head is blunter than the tail. The colour is completely bleached and the eyes are only visible faintly in the smallest specimens. On clearing the small proboscis can be seen not reaching to half the length of the body. The eyespots are very small.

Anatomy. The epithelium is very thick; the basement membrane and circular muscles very thin and equal in thickness. There are eosinophile gland cells beneath the longitudinal muscle layer ventral to the brain. The head glands are extremely developed though they do not stain with haematoxylin. They fill the head and stretch back beyond the brain and the two forward

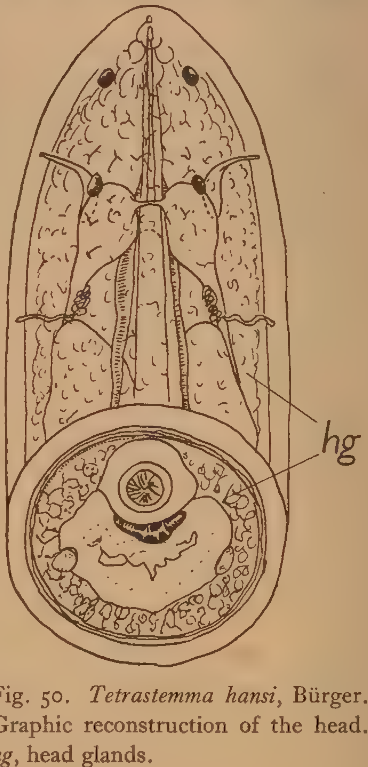

Fig. 50. *Tetrastemma hansi*, Bürger. Graphic reconstruction of the head. *hg*, head glands.

branches of the anterior caecum (Fig. 50). The nephridial tubules open to the exterior laterally at the level of the branches of the anterior caecum. The proboscis has ten nerves and is armed with the usual main stylet and two reservoirs each with two, three or four stylets. The brain is fairly large. The dorsal ganglia are smaller than the ventral and there is no strand of fibres from the former to the lateral nerves. The cerebral organs open ventro-laterally just in advance of the brain and pass inwards, increasing in size and becoming applied to the brain between the dorsal and ventral ganglia.

One of my sectioned specimens was an immature male, the other an immature female.

The identification of this form with *T. hansi*, Bürger, is based on the head glands and the cerebral organs. Both of my series of sections show two short lateral diverticula from the caecum.

Tetrastemma longistriatum, n.sp. (Plate XVI, fig. 7; Fig. 51).

This species occurred at the following stations. It was sketched and described under N 48:

St. 42. 1. iv. 26. OTL, 120–204 m. 2 (N 57).
St. 141. 29. xii. 26. BTS, 17–27 m. 2 (N 48).
St. 163. 17. ii. 27. BTS, 18–27 m. 1 (N 91).
11. iv. 27. Kelp roots, King Edward Cove, 2 (N 48).

The lengths and breadths of some of the specimens were: 10·0, 1·0 mm.; 5·0, 0·7 mm.; 5·0, 0·6 mm.; 2·0, 0·2 mm.

Form and colour in life. The body is round in section, tapering to the tail which is much more acute than the head. There is a pair of deeply embedded eyespots just in front of the head markings and another pair at the anterior end of the body pigment. The ground colour of the body is pale yellow. On the back there are two longitudinal brown bands, fading laterally, which leave a broad sharply defined streak between them. At the head the streaks end, but there is a pair of very deep reddish brown patches on the head in the form of two elongated right-angled triangles placed transversely, the right angles being the inner anterior angles.

Form and colour of preserved specimens. The length is about 5·0 mm., the breadth 0·35 mm. The body is cylindrical, the head blunter than the tail. The eyes are not visible, but on clearing, the anterior pair are larger than the posterior. The colour and markings are faintly seen.

Anatomy. The most noticeable feature of the species is the extreme development of the epithelium, which is at least twice the thickness of the remainder of the body wall. It bears within its cells large masses which stain with haematoxylin. The head glands are compact and solid masses opening just beneath the tip of the head. One strand spreads over the rhynchocoel, just reaching the brain. Another forms a thick U-shaped investment to the oesophagus but diminishes and disappears before the dorsal strand. The lateral branches of the anterior caecum overlap the dorsal ganglia (Fig. 51).

The proboscis is stout. I could not make out more than nine nerves in one of my series of sections, but there were ten in another. The armature consists of a main stylet with two reservoirs each with three stylets.

The brain is large, the dorsal ganglia being somewhat smaller than the ventral. There is no dorsal strand in the lateral nerves. The cerebral organs are small. They open laterally and only just reach the brain (Fig. 51).

Two small specimens from St. 42 were examined among the preserved material. One was sectioned and proved to be a female with large eggs. In all characters this specimen agreed with the above description.

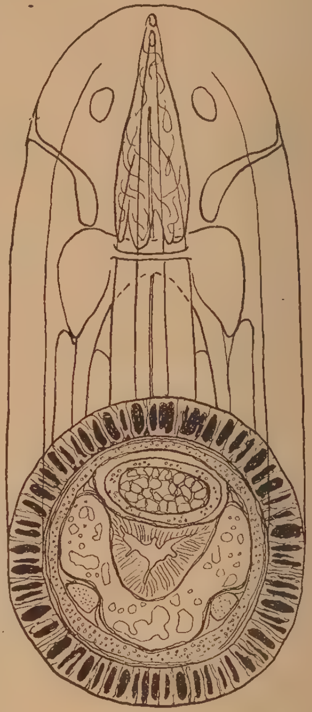

Fig. 51. *Tetrastemma longistriatum*, n.sp. Graphic reconstruction of the head and section across the body to show the extreme development of the epithelium.

Tetrastemma maivikenensis, n.sp. (Plate XVI, fig. 10).

Only the external characters of a single specimen (N 19) of this worm are known, and it bears a resemblance (except in size) to *T. vermiculus*, Quatrefages. The length in life was 40 mm., the breadth 0·75 mm. The body was soft and round, tapering to the tail. There were two pairs of eyes and the brain could be seen as a bilobed pinkish mass through the body wall. The colour was pale green except at the head which was yellowish. The distinctive marking consisted of a streak of brown pigment between the eyes of each side.

It takes its name from Maiviken, South Georgia, where the specimen was found (St. MS 70).

Tetrastemma stanleyi, n.sp. (Plate XVI, fig. 12).

Three specimens of this form were collected in Port Stanley harbour under stones at low tide on April 29, 1926 (N 21). The lengths ranged about 40·0 mm., the breadths 1·2 mm.

The body is round in section, the head slightly constricted from it, bluntly pointed and somewhat flattened. The tail tapers but ends acutely. There are from one to four eyespots in each group of the two pairs. The general colour effect is reddish brown near the head, paler towards the tail. One animal was olive green. The tip of the snout is conspicuously dark brown. This pigment is continued as a median line to the level of the posterior eyes between which it broadens and terminates. In spirit the colour is bleached. One specimen was of a dull bluish grey colour, evidently caused by the contents of the gut. No eyes could be seen even when cleared.

Anatomy. The head glands form a compact layer dorsal to the rhynchodaeum and disappear before the brain.

The epithelium is not very thick but it is equal to the three other body layers. Of these the basement membrane and circular muscles are equal in thickness and are together about one-quarter of the thickness of the epithelium. The oesophagus opens into the stomach after the brain. There is no anterior caecum and the stomach is very long.

The proboscis has fourteen nerves. One specimen had an accessory armature of two reservoirs each with two stylets; another had two reservoirs each with four.

The brain is small and the dorsal ganglia do not send fibres into the lateral nerves. The cerebral organs are small and just reach the underside of the brain. The canals open ventro-laterally.

The specimen sectioned was an immature male.

Tetrastemma validum, Bürger, 1893 (Plate XVI, fig. 1; Figs. 52, 53).

In colour and especially in form this species is the most easily recognized of the southern *Tetrastemma*. Single specimens were taken from kelp roots in King Edward Cove in 1927 (N 49) and 1929. In March 1930 thirty-eight specimens were caught by the dredge with a mass of red algae. Other captures were at St. 175 (N 130) and St. 179 (eleven specimens—N 99). The lengths ranged from 8·5 and 10·0 mm. to 35·0 and 40·0 mm. with corresponding breadths of 0·8, 1·4, 2·5 and 2·3 mm.

The body is stoutly built, flattened from above and fusiform. The head is pointed, distinct from the body by a slight "neck". Cephalic grooves join under the head in a wide V with its apex forward and from this junction another groove runs forward in the mid-ventral line. There is a groove behind these at the shallow depression of the "neck", but this is incomplete dorsally. Sometimes the posterior part of the head is round and broad, the anterior end being drawn out into a kind of beak. It has a distinctly shark-like appearance, especially pronounced from the side. The colour on the back is dark reddish brown, yellow-brown or purple-brown. The underside is white. On each side of the head a very definite almost rectangular white tag shows up strongly against the dark pigment. Just before this tag there is an encroachment of white on the pigment of the head, and in this pigmentless patch lies the first pair of eyes. The second pair is situated behind on the anterior edges of the white patches.

Form and colour of preserved specimens. The body retains its shape to a great extent. The anterior end is blunter than the tail. The back is convex, the belly flat or concave. Very little colour remains in the specimens, but usually there is sufficient duskiness to make the white patches faintly visible.

Anatomy (Fig. 52). The head glands open near the tip of the head. There are at first three strands towards the dorsal side but they soon completely fill the head. At the anterior end of the brain the dorsal glands have coalesced, while ventrally there are still small packets. The glands do not stain with haematoxylin. After the brain they persist ventral to the branches of the anterior caecum. The epithelium is thicker than the sum thickness of the other layers.

The rhynchocoel extends to the end of the body and the nerves join just behind its attachment over the gut. The proboscis possesses ten nerves (in one specimen twelve) and has two accessory stylet reservoirs each with two stylets similar to the main stylet which is 0·074 mm. long mounted on a pear-shaped base 0·101 mm. long. Branches of the anterior caecum do not reach the brain.

The brain is small. There is a dorsal strand in the lateral nerve. The cerebral organs are fairly large. They open on the under-surface of the head but do not reach the brain.

On two fronds of the red alga dredged with the large haul of this species a semi-translucent sheath was found attached. The length was 28 mm., breadth 5·0 mm. The pouch was open at both ends and from one the animal crawled while under observation (Fig. 53).

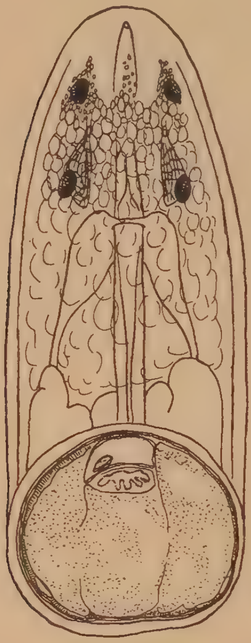

Fig. 52. *Tetrastemma validum*, Bürger. Graphic reconstruction of the head to show the development of the head glands and the position of the brain, cerebral organs, eyes and branches of the anterior caecum.

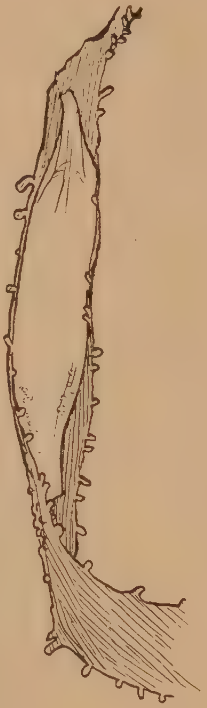

Fig. 53. *Tetrastemma validum*, Bürger. Membranous pouch, open at both ends, attached to a frond of red alga.

In several characters this species is similar to *Amphiporus michaelseni*, Bürger, as described by Joubin (1908), but the four eyes and the internal structure show that its affinities are with *Tetrastemma*.

Tetrastemma weddelli, n.sp. (Figs. 54, 55).

One specimen (N 70) was collected at St. 160 between South Georgia and the South Orkney Islands. No note was made of the colour or form, but its anatomy is so distinctive that it should be easily recognized. The body was cylindrical, 11 mm. long and 0·75 mm. broad. The proboscis was protruded to a length of 5·5 mm. and just below it was the frilled opening of the mouth. The colour was bleached (Fig. 54A).

Anatomy. A feature of the sections throughout the body is the thickness of the basement membrane (Fig. 55) which is rather thicker than the epithelium. Both circular and longitudinal muscles are strongly developed. I could not be certain of the presence of head glands owing to the peculiar staining of the head, but there appears to be a thick strand staining deeply with haematoxylin dorsal to the rhynchocoel. The proboscis has fourteen nerves and is armed with a main stylet on an elongated pear-shaped base 0·098 mm. long and two reservoirs each with two stylets. The frilled mouth is a continuation of the stomach into which the narrow folded tube expands after the brain. There is a single forward diverticulum of the gut which is lateral to the stomach and does not reach the brain. The excretory tubules open dorso-laterally above the lateral nerves.

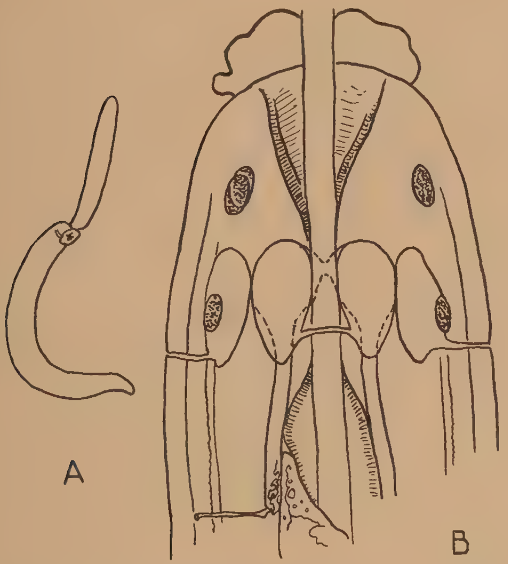

Fig. 54. *Tetrastemma weddelli*, n.sp. A, outline sketch of the preserved specimen, × 3 approx.; B, graphic reconstruction of the anterior end.

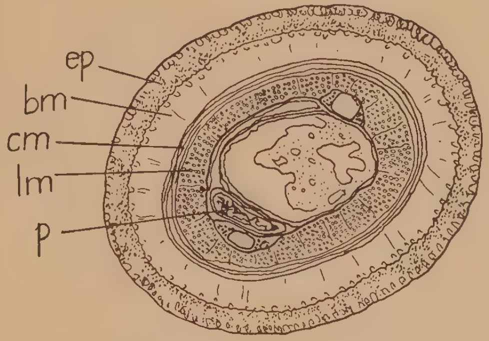

Fig. 55. *Tetrastemma weddelli*, n.sp. Transverse section across the body. *bm*, basement membrane; *cm*, circular muscles; *ep*, epithelium; *lm*, longitudinal muscles; *p*, proboscis.

There are two pairs of eyes. In this specimen there is a double eye on one side. The brain is large and the dorsal ganglia are far larger than the ventral. The ganglia of each side are close together, especially the ventral ganglia at the anterior end (Fig. 54B), so that the ventral commissure is very short. There is a dorsal strand in the lateral nerves. The cerebral organs are large and lie along the dorsal ganglia. They open laterally from their posterior ends, though whether this is connected with the pushing forward of the alimentary canal or the normal position in life I am unable to say.

The specimen was a male with ripe sperm.

PART III. THE PELAGIC NEMERTEANS

Forty-five pelagic Nemerteans were included in the collection. Of these, thirty-five proved to be *Pelagonemertes rollestoni*, one of which, taken from a haul of seventeen at St. 107, was sketched in life. Most of the specimens were noted when captured but only one other colour sketch was made. This is reproduced in Plate XVI, fig. 5, and is a new species, *Bathynemertes hardyi*.

I have followed Brinkmann (1917) in his classification of the suborder Polystilifera, tribe Pelagica.

Genus Bathynemertes Brinkmann

Bathynemertes hardyi, n.sp. (Plate XVI, fig. 5; Figs. 56, 57).

This interesting form, curiously substantial for a pelagic worm, was sketched and noted in life by Mr (now Prof.) A. C. Hardy. It was captured at St. 86 (33° 25′ 00″ S, 6° 31′ 00″ E) in the 4½ m. net at 1000 (–0) m. The body was scarlet with black irregular markings; the proboscis lighter than the body. The body was almost round in section, tapering a little to the head and considerably at the tail which was not expanded into a fin.

Form and colour of preserved specimen. The body is 110 mm. long, with a maximum breadth and thickness of 25 and 13 mm. It is somewhat flattened and is faintly marked by narrow annular wrinkles. The tail is more definitely flattened. It has, however, neither fins nor lateral lappets. The body has a tendency to curl up at the ends due perhaps to the greater shrinkage of the proboscis and rhynchocoel wall towards the dorsal side of the body cavity (Fig. 56).

The mouth is not coincident with the rhynchodaeum and has a frilled edge. The proboscis is very strong. It is 8 mm. in diameter and covered with papillae. The rhynchocoel extends into the tail.

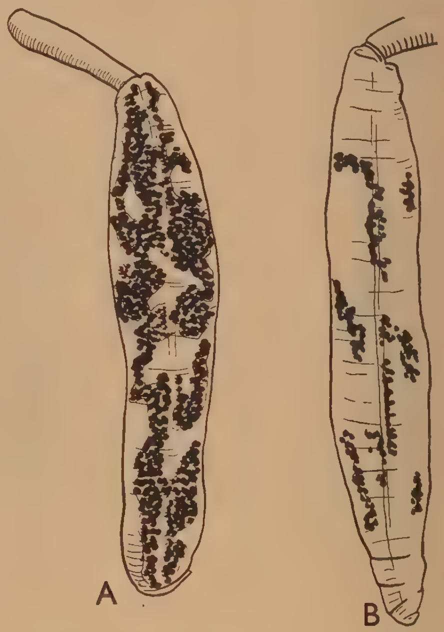

Fig. 56. *Bathynemertes hardyi*, n.sp. A, ventral, B, dorsal aspect of the preserved specimen. × ⅔ approx.

The body colour is light brown-orange with irregular patches of dark brown pigment especially on the under side. A lighter streak can be seen down the mid-dorsal and mid-ventral lines, and on each side there is a pale slightly raised lateral line breaking the pigment patches.

Anatomy (Fig. 57A). The epithelium is almost entirely absent; what there is being ventral (Fig. 57B). The basement layer is very thick and the circular and longitudinal muscles are fairly developed, little thinner laterally than dorsally or ventrally. Strong strands of muscle pass from the dorsal to the ventral body wall through the body.

The alimentary canal opens at the frilled mouth; there is no oesophagus. The branches of the gut are small but numerous anteriorly, and they reach forward to the brain.

The proboscis has twenty-four nerves and is armed by the usual curved rod, although no stylets could be seen. The rhynchocoel wall consists of interlaced longitudinal and circular fibres. The brain is not large. Its structure, with the strands of nerve fibres passing from the dorsal ganglia into the lateral nerves, corresponds with the description given by Brinkmann for *B. hubrechti*. I could find no dorsal nerve between basement membrane and circular muscles such as Bürger, 1907 (1912), describes in *Drepanophorus pelagicus*.

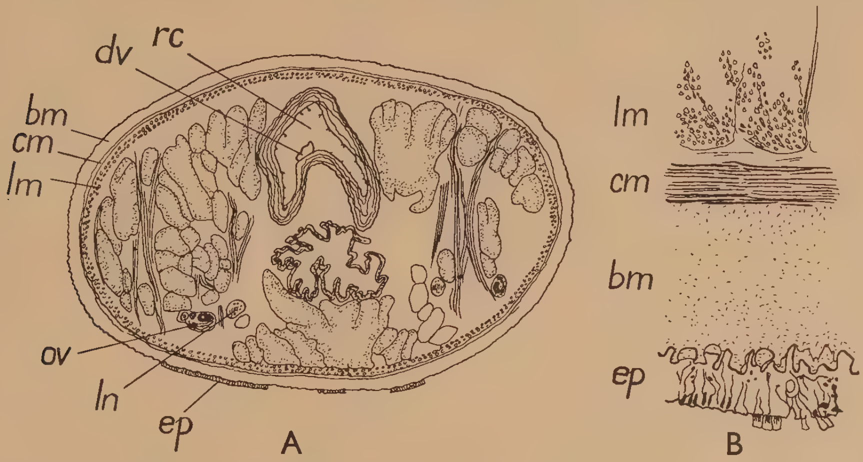

Fig. 57. *Bathynemertes hardyi*, n.sp. A, transverse section towards the anterior end of the body. *bm*, basement membrane; *cm*, circular muscle layer; *dv*, dorsal vessel; *ep*, epithelium; *lm*, longitudinal muscle layer; *ln*, lateral nerve; *ov*, gonad; *rc*, rhynchocoel. B, section of the body wall, from A, magnified.

The specimen was a female with small eggs. The gonads were only seen towards the ventral side close to the lateral nerves.

Bathynemertes hubrechti, Brinkmann, 1917 (Figs. 58, 59).

Four specimens of fair size were collected at the stations given below:

St. 85. 23. vi. 26. 33° 07′ 40″ S, 4° 30′ 20″ E. N 450 H, 2000 (–0) m. "Scarlet" (N 168).

St. 89. 29. vi. 26. 34° 05′ 15″ S, 16° 00′ 45″ E. TYF, 1000 (–0) m. "Dull orange" (N 160).

St. 100*c*. 4. x. 26. 33° 20′ to 33° 46′ S, 15° 18′ to 15° 08′ E. TYF, 2500 (–0). "Bright brick red" (N 167).

St. 101. 15. x. 26. 33° 50′ to 34° 13′ S, 16° 04′ to 15° 49′ E. N 450, 1310–1410 m. "Orange red" (N 164).

The sizes in spirit were:

Serial No.	Length mm.	Greatest breadth mm.	Depth mm.
N 168	20·0	5·0	3·0
N 160	7·0	1·3	1·2
N 167	30·0	6·0	4·0
N 164	21·0	5·0	4·0

The form is flattened and bluntly pointed at both ends. Some degree of translucency may be observed but there is no colour (Fig. 58).

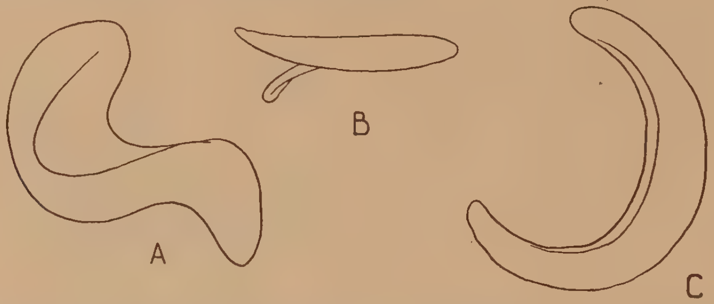

Fig. 58. *Bathynemertes hubrechti*, Brinkmann. Outline sketches of the preserved specimens. A, N 164 anterior end above; B, N 160 from the side; C, N 168 from the side.

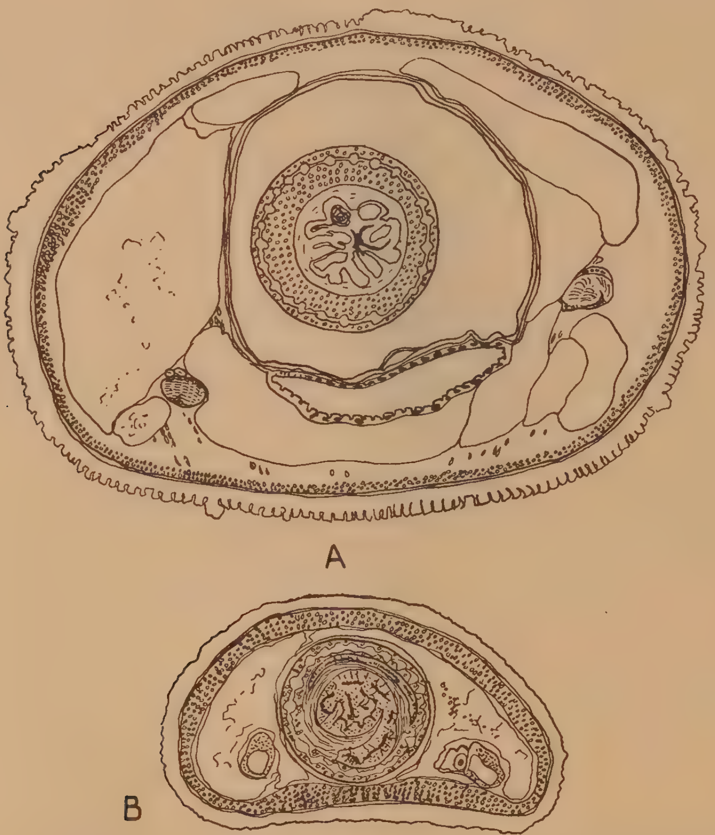

Fig. 59. *Bathynemertes hubrechti*, Brinkmann. A, transverse section through the body near the head (N 164); B, transverse section farther back (N 160).

Anatomy (Fig. 59). In all specimens the epithelium is missing. The basement membrane is high and serrated but not much stained. The musculature is reduced laterally and is thin dorsally and ventrally although it is thicker in the small specimen (N 160) than in the larger. There is no oesophagus. The gut branches fill the body cavity and the lateral nerves are included among them and not pressed against the body wall. The rhynchocoel extends to the posterior end of the body. Its wall consists of interlaced fibres. The proboscis is very stout and the number of nerve strands varies between 22 (N 160), 24 (N 168), 25 (N 164) and 26 (N 167). The brain is of fair size and conforms to the description given by Brinkmann (1917).

N 160 and 164 were female. Small eggs could be seen close beside the lateral nerves (Fig. 59B). In the other specimens I could find no trace of gonads.

Genus **Crassonemertes**, Brinkmann

Crassonemertes robusta, Brinkmann, 1917 (Fig. 60).

No colour note was made of this specimen (N 170), taken with *Nectonemertes kempi* in a 2-metre net at lat. 6° 55′ N, 15° 54′ W, 0–800 m.

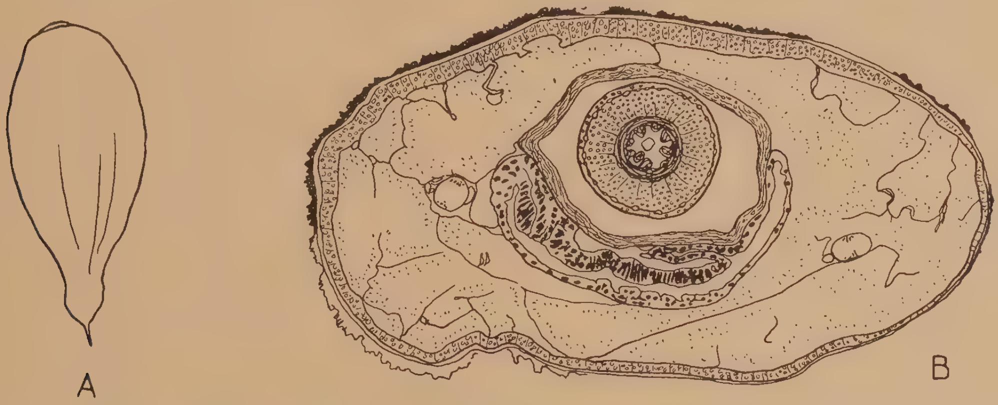

Fig. 60. *Crassonemertes robusta*, Brinkmann. A, dorsal surface, × 3; B, transverse section at the anterior end.

In spirit the body is white (it had been fixed in corrosive sublimate) and completely opaque. It is broad and flattened and has a distinct tail. A sharp end protruded from the tail; this was afterwards found to be the proboscis (Fig. 60A). The length is 15·0 mm., greatest breadth 7·0 mm., thickness 5·0 mm.

No epithelium is present. The basement layer is deeply stained and appears to have suffered from shrinkage or drying. The muscle layers are reduced, except dorsally (Fig. 60A). There is no oesophagus. The muscular stomach opens into the long pylorus at the brain. The gut branches are wide and very numerous. They fill the body cavity so that no sign of separate diverticula can be seen in the posterior part of the body when cleared with anilin oil.

The proboscis is very stout and long. It has twenty-one or twenty-two nerves. The wall of the rhynchocoel is composed of interlacing fibres. The brain is small. There does not appear to be a dorsal strand in the lateral nerves. No gonads could be made out.

Genus Nectonemertes, Verrill (part)

Nectonemertes mirabilis, Verrill, 1892 (Fig. 61).

A note was made that the colour in life of this specimen was "pinky red". It was taken at St. 87.

The length of the preserved specimen (N 80) was 14 mm., breadth 2·1 mm., thickness 1 mm. The colour was yellow and semi-transparent. The anatomy has been thoroughly described by previous workers. This specimen was a female with large eggs. The proboscis was missing. An outline sketch is given in Fig. 61 to show the form of the body and the position of the gonads.

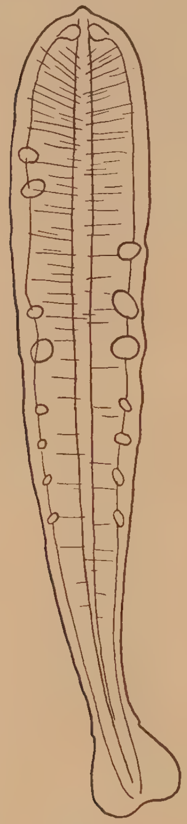

Fig. 61. *Nectonemertes mirabilis*, Verrill. Outline sketch showing the form of the body and the position of the gonads. × 7.

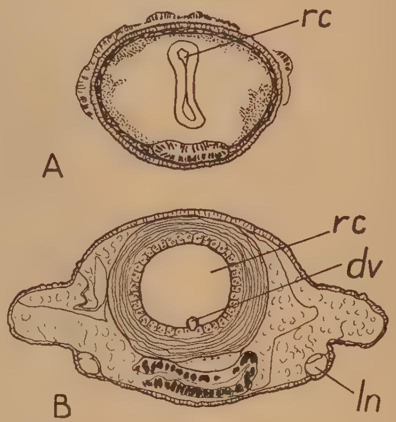

Fig. 62. *Nectonemertes kempi*, n.sp. A, transverse section through the brain. B, transverse section through the body. *dv*, dorsal vessel; *ln*, lateral nerve; *rc*, rhynchocoel.

Nectonemertes kempi, n.sp. (Fig. 62).

A small worm was collected with *Crassonemertes robusta* from 0–800 m. at 6° 55′ N, 15° 54′ W. It was fixed in corrosive sublimate. No note was made of the colour and form in life. The preserved specimen (N 169) was 7 mm. long and resembled the post-larval stage of a fish. It was white, somewhat flattened and had a tail fin.

The sections show a very large brain (Fig. 62A) completely filling the head. It seems evident, however, that the specimen has suffered shrinkage from the fixative and this has probably affected the basement layer and muscles. The most striking feature apart from the size of the brain is the thickness and size of the rhynchocoel and its wall. The latter is composed of an inner longitudinal layer definitely divided into bundles and an outer thick layer composed of circular fibres with some longitudinal fibres among them. Before the brain the muscle layers are reversed, i.e. the inner layer is circular and the outer longitudinal. The proboscis is missing.

There is no oesophagus. The branches of the gut reach forward beside the brain posteriorly.

The lateral nerves are pressed against the ventral body wall (Fig. 62 B) and contain an evident dorsal strand.

The specimen was a female with eggs developing singly close beside the larval nerves.

That the animal belongs to the genus *Nectonemertes* is certain from its form, the muscles of the rhynchocoel wall and the position of the lateral nerve cords. I have separated it from Brinkmann's species—*primitiva* and *minima*—on the ground of its form and the size of the rhynchocoel and brain.

Genus Pelagonemertes

Pelagonemertes rollestoni, Moseley, 1875 (Fig. 63).

The following captures were made of this species:

St. No.	Date	Gear	Depth	No. of specimens	Sex	Serial No.
—	2. ii. 25	N 200	0–800	1	♀	N 139
71	30. v. 26	N 70 V	1000–750	1	—	N 145
		TYF	2000 (–0)	1	♀	N 149
72	1. vi. 26	N 450	2000 (–0)	1	♀	N 141
76	5. vi. 26	N 450 H	1500–0	1	♂	N 147
78	12. vi. 26	TYF	1000 (–0)	3	♀♀?	N 143
79	13. vi. 26	N 450 H	1000–0	1	♀	N 140
85	23. vi. 26	N 450 H	2000 (–0)	1	♂	N 154
86	24. vi. 26	N 450 H	1000 (–0)	1	?	N 146
89	28. vi. 26	TYF	1000 (–0)	2	♂	N 158
					♂	N 163
107	4. xi. 26	N 450	850–950	17	9♀, 3♂	N 138
					♀	N 42
256	23. vi. 27	TYF	850–1100 (–0)	1	♀	N 151
395	13. v. 30	N 450 H	1500–1600	3	♂♂	—
405	4. vi. 30	TYFB	2200–0	1	♀	—

A specimen from the large haul at St. 107 was sketched directly after capture. An outline drawing of this sketch is given in Fig. 63 to which the imagination can readily add the transparency of the body, the opacity of the brain, lateral nerves, gonads, proboscis and its sheath, and the startlingly vivid colouring of yellow on red of the branches of the gut. This specimen measured in life 45 mm., and was 23 mm. broad. Another was 21 and 12 mm.

After fixation the gut branches appear considerably thicker than they are in life. The variation in number of branches and in the size of the animal can be gauged from the following:

Length mm.	Breadth mm.	Thickness mm.	Gut branches
33·0	22·0	7·0	15 : 15
21·0	15·0	—	16 : 14
30·0	21·0	6·0	17 : 17
20·0	13·0	—	15 : 17
30·0	20·0	—	17 : 16
35·0	18·0	—	14 : 15
22·0	18·0	—	13 : 13
16·0	8·0	—	14 : 15
22·0	16·0	6·0	13 : 14
13·0	12·0	—	16 : 16

The anatomy of this species has been worked out very thoroughly by Bürger, 1907 (1912), and Brinkmann 1917. Fig. 63B shows the position of the testes and gives an idea, when compared with Fig. 63A, of the degree of enlargement of the gut branches after fixation. The number of nerves in the proboscis was twenty-two in two of my specimens, but they are difficult to count because of the irregular thickening of the nerve

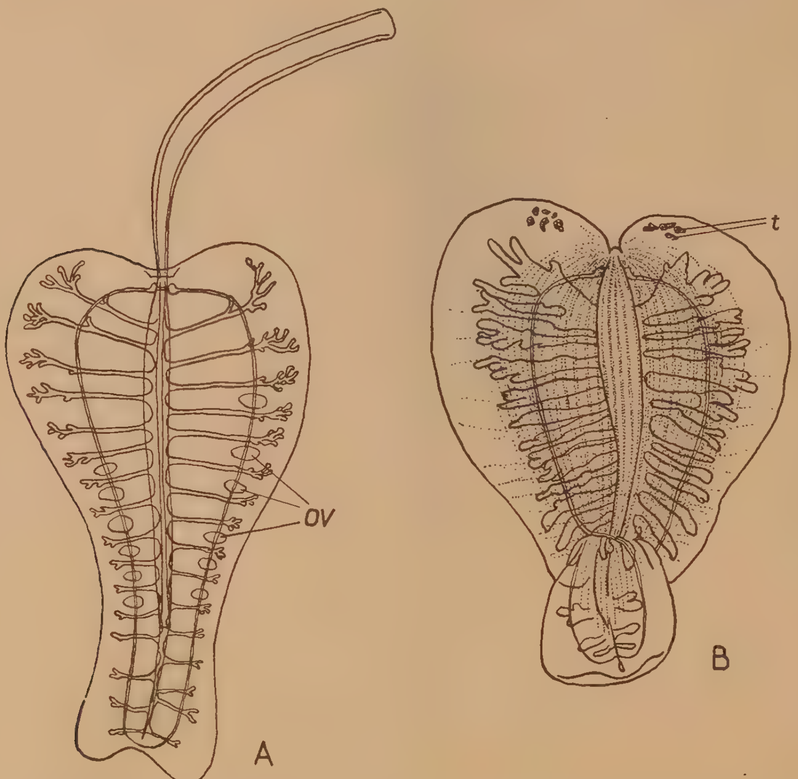

Fig. 63. *Pelagonemertes rollestoni*, Moseley. Outline sketches of entire animals. A, female, from a colour sketch of a living animal; B, male, from a spirit specimen. *ov*, ovaries; *t*, testes. × 2.

net. Brinkmann gives sixteen nerves. I have examined my series of sections for the rudimentary eyes and in two males several small organs corresponding to the description and figures (Brinkmann, 1917) were found on each side of the lappet of the body ventrally very close beside the rhynchodaeum, but I could not trace them in the female.

Genus **Probalaenanemertes**, Brinkmann

Probalaenanemertes irenae, n.sp. (Figs. 64, 65).

Two specimens of this form were collected at St. 89. The colour notes were "scarlet with orange spots down sides" (N 161); "pale orange with deep rose pink spots down sides" (N 162). In spirit the sizes were: length 9·0 and 17·0 mm.; greatest breadth 3·0, 3·5 mm.; thickness 1·7, 2·0 mm. Both were somewhat flattened, bluntly pointed at the thicker end of the body and with a distinctly flat spade-shaped tail (Fig. 64). In one five brownish gonads could be seen on each side and the lateral nerves were faintly visible outside them; in the other there were fourteen gonads on one side, twelve on the other. The colour was pale brown and the bodies were translucent.

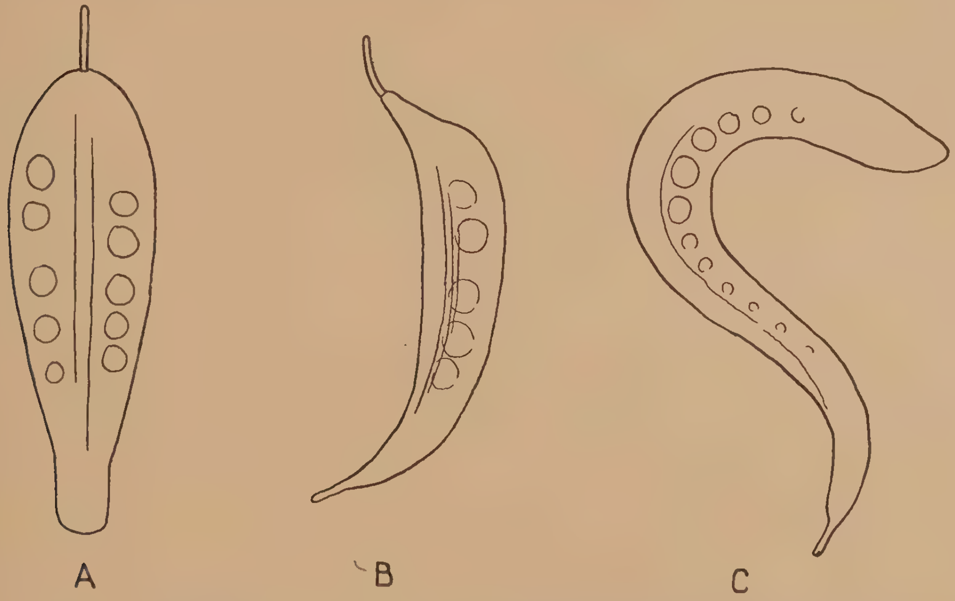

Fig. 64. *Probalaenanemertes irenae*, n.sp. Outline sketches of the preserved specimens. A, N 161, dorsal; B, lateral; C, N 162, lateral. × 4 approx.

Anatomy (Fig. 65). The epithelium is present in patches at the anterior end and is a deep layer into which the serrated basement layer penetrates deeply (Fig. 65A). The circular and longitudinal muscles are very much reduced, especially the former. At the tail there are dorsal and ventral median strengthening strands of longitudinal muscle (Fig. 65C). There is no oesophagus. The folded tube shown in Fig. 65A passes back unbranched through the brain region and beyond. Meanwhile two gut branches have appeared above and lateral to the brain and farther back more appear which invade the body cavity ventrally and finally open into a short median anterior caecum ending blindly forwards.

The rhynchocoel is spacious but the wall is thin. It is composed of inner longitudinal and outer circular muscles and extends nearly to the end of the body. The proboscis is thin and the muscles are poorly developed. It possesses seventeen nerves.

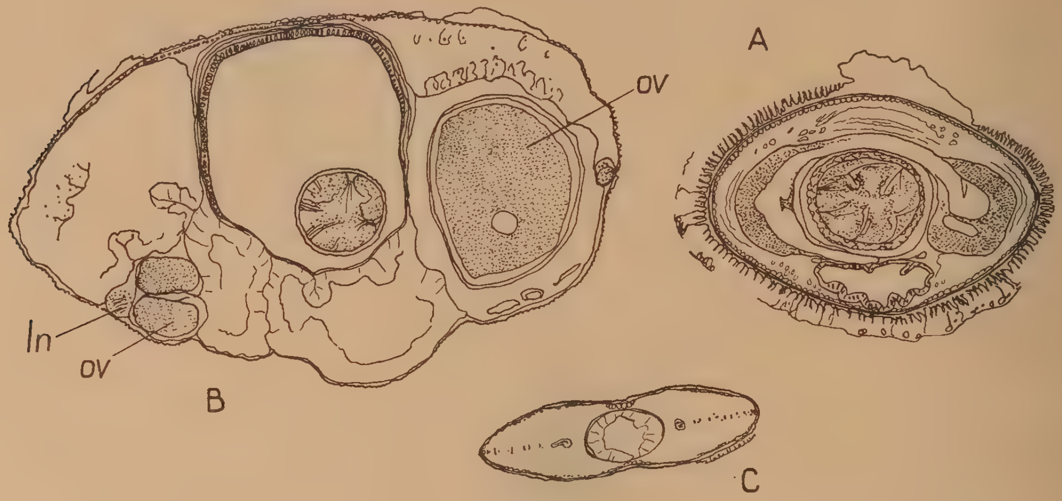

Fig. 65. *Probalaenanemertes irenae*, n.sp. Transverse sections. A, the region of the brain; B, mid-body; C, tail. *ln*, lateral nerve; *ov*, egg.

The brain is fairly large, dorsal ganglia rather larger than ventral. The lateral nerves, containing a distinct mass of fibres from the dorsal ganglia, are pressed ventrally until they rest against the muscles of the body wall and close to them towards the middle line the gonads begin development. The eggs are immense (Fig. 65B).

NOTES ON THE DISTRIBUTION OF THE SOUTHERN NEMERTEANS

The extension of the Mediterranean fauna to the south western extremity of Africa has already been indicated. Certain species, of course, can be reckoned as cosmopolitan and their occurrence leads to no comment; for instance, *Lineus ruber*, *Tetrastemma candidum* and *Amphiporus pulcher*, which have been found widely distributed in the temperate seas in the northern hemisphere: but the inclusion of *Tubulanus nothus*, *Nemertopsis tenuis*, *Lineus bilineatus* and *Cerebratulus fuscus*—all easily identified by striking colour, markings or body form apart from their anatomy—points to a common origin with the fauna of the Mediterranean even if there is discontinuity across the equatorial region where at present the littoral fauna is not known. That more records are not available from southern waters is probably an expression of the relatively little systematic work that has been done south of the equator in comparison with the northern coast lines. *Amphiporus pulcher* has been recorded from Chili (Isler), *Tubulanus* *annulatus* from the Cape of Good Hope (Stimpson) with *Tetrastemma candidum*, although the latter was described under the name *T. incisum*.

Dredging off the west coast of Africa was unfortunately not undertaken outside Saldanha Bay. I should expect *Baseodiscus delineatus* to appear in the collection notwithstanding its absence from the littoral fauna.

The material from South Georgia and the Falkland Islands consists of sub-Antarctic and Antarctic species peculiar to these regions; with representatives of the genera *Lineus*, *Cerebratulus*, *Amphiporus* and *Tetrastemma* in great diversity and numbers of individuals. The Paleonemertea are apparently not represented in the far south. Most of the forms taken are widespread or occur in the catches as isolated specimens from which no deduction as to distribution can be made. *Lineus longifissus* is an exception. This species was collected by H.M.S. 'Challenger' from a depth of 126 metres off Marion Island and described by Hubrecht from one complete and one fragmentary specimen. At St. 167 the R.R.S. 'Discovery' took this species again from a depth of 244–344 m. off Signy Island in the South Orkney group. This was perhaps the most curious haul made, for at this one station two nets attached to the back of the trawl produced between them twenty-five specimens. The same gear was used off South Georgia, the South Shetlands and the Falkland Islands, but no other specimen was captured. The only parallel instance that occurred among the Nemerteans was the haul of seventeen *Pelagonemertes rollestoni* in one haul of the 4½ m. net at St. 107. *Pelagonemertes*, however, is a purely pelagic form, and swarming or "patchiness" in pelagic animals is a recognized phenomenon, not necessarily connected with breeding and sometimes on a large scale (as in *Euphausia superba*), so that the two hauls are not really comparable. What is interesting is the connection of Marion Island with the Antarctic by the occurrence of this species and of *Amphiporus marioni*, Hubrecht, now recorded from South Georgia, just as Kerguelen is linked by *Lineus corrugatus*, McIntosh, and *Amphiporus moseleyi*, Hubrecht, and both are separated from the northern continent by the dissimilarity in their Nemertean faunas. Coe (1905, p. 77) suggested that ocean currents with limiting climatic conditions are a factor, if not the factor, in the dispersal of Nemerteans in the Bering Sea. Applied to the data given above, however, dispersal by ocean currents does not seem a possible hypothesis, for it is difficult to understand how the current which passes up the coast of West Africa could have influenced the dispersal of the northern littoral forms to the southward, or, supposing dispersal took place in the opposite direction, why *Lineus corrugatus* has not become established on the West African coast with the help of the cold Benguela current. The facts indicate, I think, a creeping dispersal along an unbroken coastline, or at any rate a line of shallows with no extensive deep-water masses in the path of dispersal; and they suggest, in addition, that both Marion Island and Kerguelen were once more intimately connected with Antarctica than they now are.

The stations at which pelagic forms were captured are shown in Fig. 66. The most frequent capture was *Pelagonemertes rollestoni*, widely distributed in the South Atlantic and Indian Oceans and also ranging north of the Equator. *P. rollestoni* has always been taken in deep-water nets, yet the depth at which it lives has not been definitely settled. We have now an observation with a closing net which indicates 850–950 m. between 1 and 4 p.m.; another, at which only one specimen was captured, of 750–1000 m. between 10 and 11 a.m.; and a third of 1500–1600 m. between noon and 3.30 p.m.

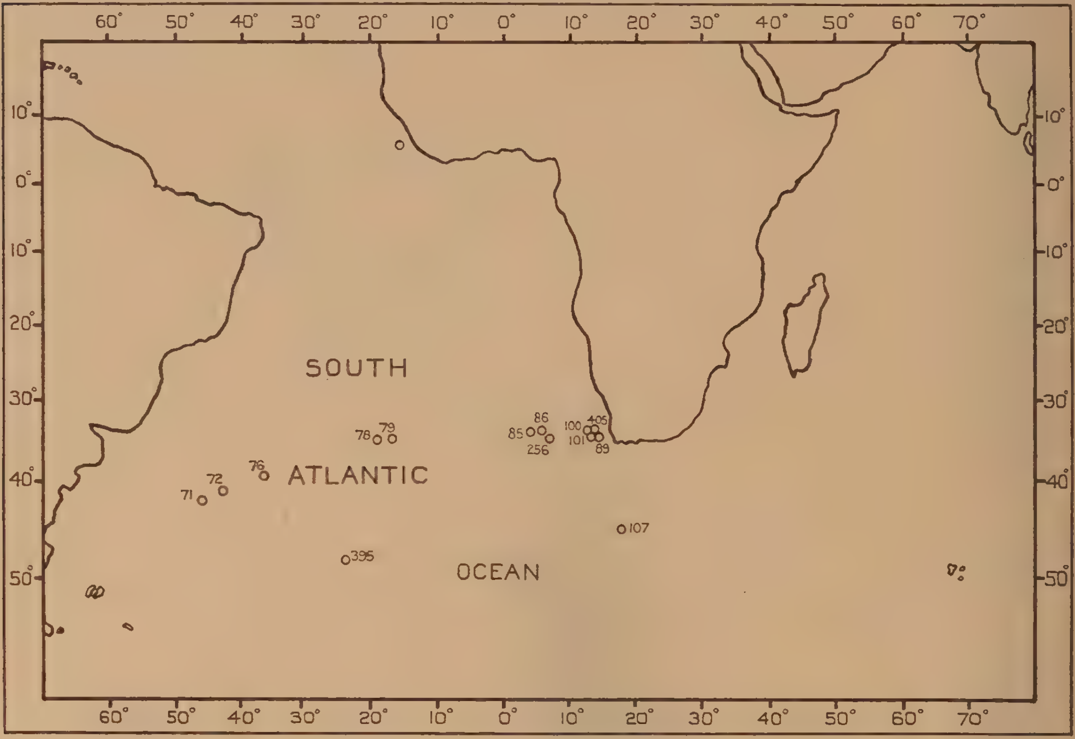

Fig. 66. Station positions at which pelagic Nemerteans were captured.

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  nigrolineatum, 225, **244**
  stanleyi, **276**
  validum, 222, **277**
  vermiculus, 276
  weddelli, 222, **278**
Tubulanus annulatus, 228, 288
  banyulensis, 228
  nothus, **225**, 228, 288

validum, Tetrastemma, 222, **277**
validus, *Cerebratulus*, 250, 253
vermiculus, Tetrastemma, 276
virescens, Zygonemertes, 243

weddelli, Tetrastemma, 222, **278**

Zygonemertes capensis, 225, **239**
  virescens, 243

PLATE XV

Fig. 1. *Tubulanus nothus*, Bürger. × 2.
Fig. 2. *Tubulanus nothus*. Head from above.
Fig. 3. *Zygonemertes capensis*, n.sp., green variant. × 5.
Fig. 4. *Lineus ruber*, O. F. Müller. Head. × 6.
Fig. 5. *Cerebratulus aerugatus*, Bürger. Head. × 6.
Fig. 6. *Zygonemertes capensis*, n.sp. Head of colourless variant. × 5.
Fig. 7. *Nemertopsis tenuis*, Bürger. × 1½.
Fig. 8. *Cerebratulus fuscus*, McIntosh. × 5.
Fig. 9. *Tetrastemma nigrolineatum*, n.sp. Head. × 10.
Fig. 10. *Lineus bilineatus*, Renier. × 10.
Fig. 11. *Oerstedia maculata*, n.sp. × 10.
Fig. 12. *Zygonemertes capensis*, n.sp. Brown variant. × 5.
Fig. 13. *Amphiporus pulcher*, Johnston. × 5.
Fig. 14. *Emplectonema ophiocephala* (Schmarda). × 5.
Fig. 15. *Tetrastemma candidum*, O. F. Müller. Head. × 5.

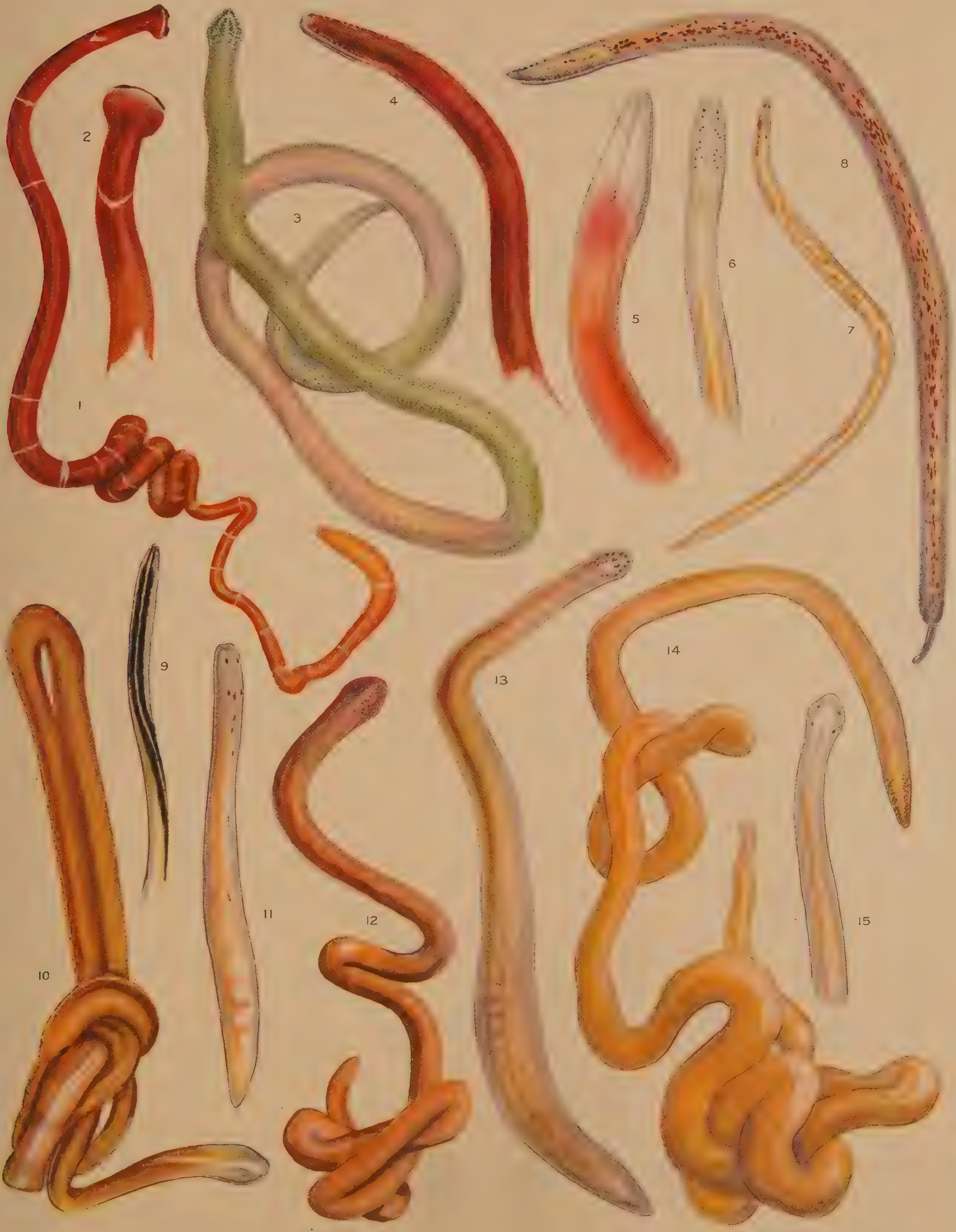

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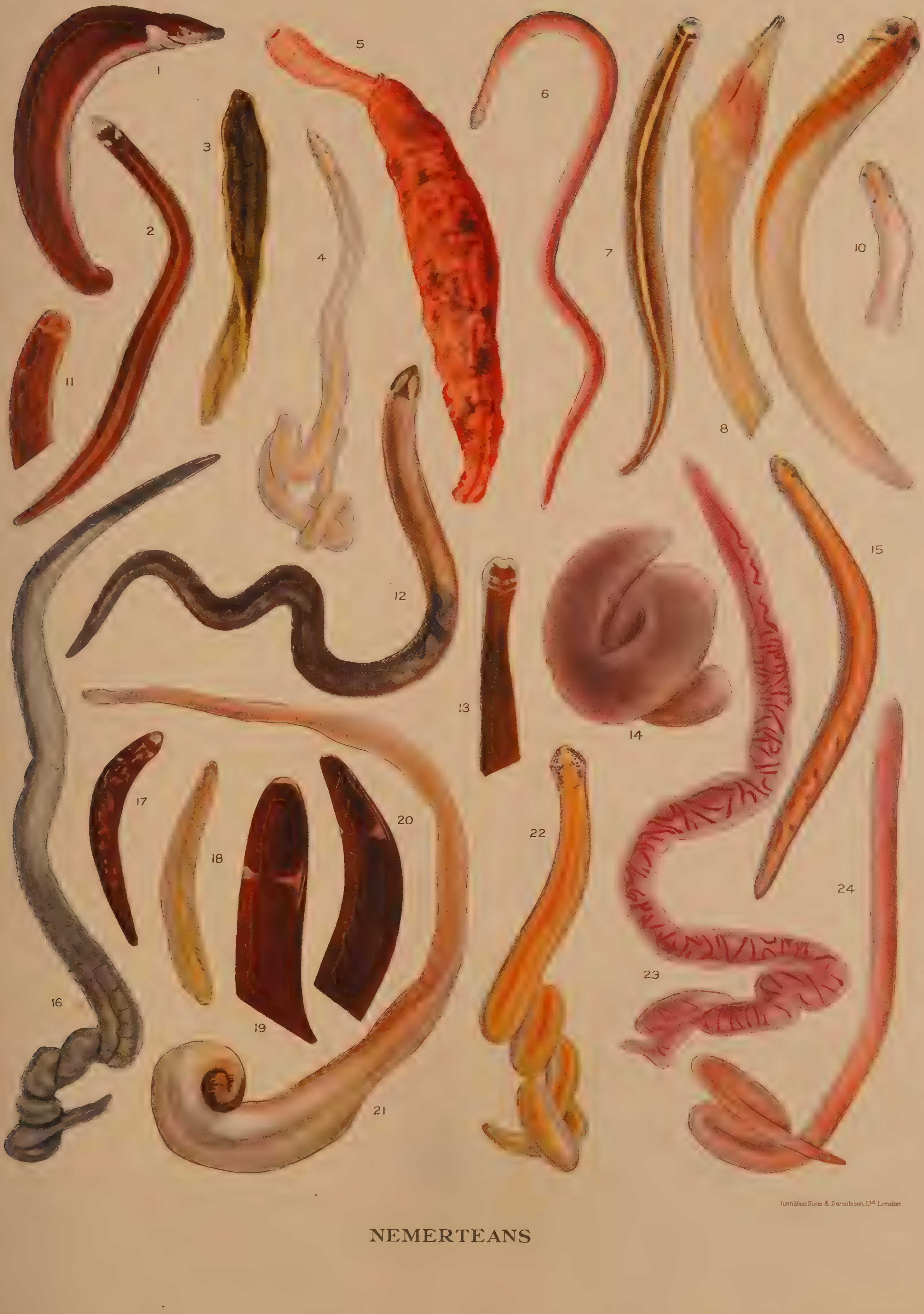
PLATE XVI

Fig. 1. *Tetrastemma validum*, Bürger. × 3.
Fig. 2. *Tetrastemma georgianum*, Bürger. × 5.
Fig. 3. *Amphiporus moseleyi*, Hubrecht. × 1.
Fig. 4. *Tetrastemma esbenseni*, n.sp. × 5.
Fig. 5. *Bathynemertes hardyi*, n.sp. × 1.
Fig. 6. *Tetrastemma hansi*, Bürger. × 10.
Fig. 7. *Tetrastemma longistriatum*, n.sp. × 10.
Fig. 8. *Cerebratulus larseni*, n.sp. Head. × 5.
Fig. 9. *Amphiporus lecointei*, Bürger. × 4.
Fig. 10. *Tetrastemma maivikenensis*, n.sp. Head. × 5.
Fig. 11. *Tetrastemma gulliveri*, Bürger. Head. × 5.
Fig. 12. *Tetrastemma stanleyi*, n.sp. × 3.
Fig. 13. *Tetrastemma georgianum*, Bürger. × 6.
Fig. 14. *Parapolia grytvikenensis*, n.sp. × 6.
Fig. 15. *Tetrastemma hansi*, Bürger. × 10.
Fig. 16. *Lineus corrugatus*, McIntosh. × 1.
Fig. 17. *Tetrastemma gulliveri*, Bürger. × 5.
Fig. 18. *Amphiporus moseleyi*, Hubrecht. × 1.
Fig. 19. *Lineus corrugatus*, McIntosh. Head. × 3.
Fig. 20. *Lineus corrugatus*, McIntosh. Head. × 3.
Fig. 21. *Lineus corrugatus*, McIntosh. × 1.
Fig. 22. *Amphiporus spinosus*, Bürger. × 3.
Fig. 23. *Tetrastemma esbenseni*, n.sp. × 5.
Fig. 24. *Lineus roseocephalus*, n.sp. × 3.



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[*Discovery Reports. Vol. IX, pp.* 295–350, *Plates XVII–XXII, December* 1934]

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INVESTIGATIONS

THE SEA-FLOOR DEPOSITS

I. GENERAL CHARACTERS AND DISTRIBUTION

By

E. NEAVERSON, D.Sc., F.G.S.

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THE SEA-FLOOR DEPOSITS

I. GENERAL CHARACTERS AND DISTRIBUTION

By E. Neaverson, D.Sc., F.G.S.

(Plates XVII–XXII)

INTRODUCTION

In 1929 142 samples of sea-floor deposits, collected during voyages of R.R.S. 'Discovery' and R.R.S. 'William Scoresby', were sent to Professor P. G. H. Boswell for examination by himself and his colleagues on the staff of the Department of Geology, University of Liverpool. Before the writer's part of the task was completed additional samples collected on later voyages became available, and descriptions of this material are now incorporated in this report. Most of the samples are numbered according to the observation stations on the voyages, thus giving a chronological arrangement, which is retained in the detailed descriptions of the samples. In an account of the distribution of the sediments a regional classification is more convenient. Such is shown in the accompanying table, the regions being defined on the basis of maps which are appended to the official Station Lists. Sixteen of the earlier samples are not numbered, but the latitude and longitude of the localities are recorded. These samples are now indicated by the letters A to P, and are placed in their appropriate position in the geographical classification.

The purpose of this report is to record the general characters and distribution of the sea-floor deposits before the samples are used for a detailed mineralogical analysis. The station numbers are those given in the official Station Lists; the localities of the 'William Scoresby' are distinguished by prefixing the letters WS to the number. Precise determination of organic species is not attempted here; such detail is not considered to lie within the scope of a report on general characters of the sea-floor deposits. In many cases, however, genera of diatoms, Foraminifera and Radiolaria are noted where they are abundant or otherwise conspicuous. Similarly the specific identification of minerals is left over for the future report on the mineralogical characters of the deposits. Casual reference, however, is made to certain minerals when they are especially significant or abundant. Such references are, for example, to the abundance of well-formed crystals of hypersthene at stations around the Falkland Islands (p. 305); the plentiful occurrence of volcanic glass in deposits around the South Shetland Islands (p. 308); the abundance of glaucophane in deposits from the western part of Bransfield Strait (p. 309); and the sporadic occurrence of phillipsite at several localities in the southern oceans.

Table I

Region	Plate	Locality numbers in Station List	
		R.R.S. 'Discovery'	R.S.S. 'William Scoresby'
1. Mid and South Atlantic	XVII	8, 9, 10, 11, 12, 63, 64, 71, 74, 77, 78, 83, 84, 89, 117, 160, 162, 167, 169, 212, 235, 236, 237, 363, 366, 1165, A, B, C, D, E, F, G, J	128, 129, 201, 202, 203, 204, 205, 255, 314, 317, 319, 374, 377, 381, 403, 406, 428, 429, 433, 468, 469, 470, 471, 472, 474, 518, 520, 521, 522, 524, 525, 526, 768
2. West and South coasts of Africa	XVII	93, 94, 95, 96, 97, 98, 101, 102, 263, 264, 265, 271, 283, 425, K, L, M	
3. Falkland Islands	XVIII	48, 51, 228, 230	71, 76, 77, 78, 79, 80, 83, 84, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 108, 109
4. South Georgia	XIX	13, 14, 15, 16, 19, 20, 23, 28, 29, 30, 31, 41, 42, 123, 129, 131, 136, 145, 151, 157, H, I, MS 68	18, 20, 26, 28, 32, 33, 37, 39, 40, 41, 42, 43, 45, 46, 47, 48, 49, 50, 52, 63, P
5. South Shetlands	XX	171, 172, 175, 180, 185, 187, 191, 192, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 206, 209, 211, N, O	382, 383, 384, 385, 386, 387, 388, 389, 391, 392, 393, 394, 395, 396, 397, 399, 400, 475, 476, 477, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 493, 494A, 494B
6. Bellingshausen Sea	XXI		495, 496, 497, 498, 499, 501, 502, 503, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517
7. West coast of South America	XXII		591, 596, 597, 598, 599, 602, 604, 605, 610, 616, 617, 619, 622, 623, 638, 639, 640, 641, 642, 647, 648, 649, 650, 651, 652, 655, 658, 663, 664, 665, 666, 667, 669, 671, 676, 677, 678, 680, 686, 689, 692, 694, 696, 697, 700, 701, 702, 703, 705, 708, 711, 717

CLASSIFICATION OF THE DEPOSITS

In this report the well-known classification of marine deposits, devised by Murray and Renard,[1] is followed in the main. Most of the samples are already named on this basis in the official Station List. But as the investigation proceeded it became evident that some of these terms (presumably based on a necessarily casual examination on board ship) are not sufficiently precise for a formal description. Moreover it is thought desirable to modify the classification of Murray and Renard to a slight extent.

---

[1] Murray, J. and Renard, A. F., 1891. The Deep Sea Deposits. *Challenger Reports.*

It has long been recognized that the dividing line between pelagic and terrigenous deposits is indefinite, and that deep-sea oozes may contain a slight proportion of detrital material transported from areas of denudation. But many of the deposits named "diatom ooze" in the official Station List have a predominance of detrital grains, although diatoms may occur in considerable abundance. Here, such deposits are classified as "diatomaceous mud", a term which indicates the importance of both organic and mineral material in their constitution. Some samples labelled "green mud" are also placed in this new category.

A constant feature of the diatomaceous muds is the abundance of flocculent material which encloses and buoys up quantities of detrital mineral grains. This flocculent substance is apparently formed largely of perishable organic debris (such as algae and animal plankton in various stages of decomposition), which is capable of drifting some considerable distance. The flocculent masses must form an important factor in the transport of terrigenous material which is sometimes found in surprising abundance at considerable depth. As far as the writer is aware this factor has only been noted casually in published works, but is evidently of wide application. The same phenomenon has been observed in black muds (fetid with sulphuretted hydrogen and containing sporadic oil globules) from the margins of the Wash, and from submerged banks in the estuary of the River Mersey in England. Here, the organic debris clings round the detrital quartz grains, and masses of the combined material float in moving water; when movement ceases they sink rapidly and soon become agglutinated.[1] The whole question seems to call for detailed observation over a wider field.

"Green mud", as the term is usually defined, is distinguished by the abundance of the mineral glauconite, which is sufficient to impart the characteristic green colour to the deposit. In many of the so-called "green muds" in the Discovery collection, no grains of glauconite have been noted. In these instances the green colour appears to be due to the presence of chlorophyll, the green colouring matter which occurs in the chromatophores of diatoms and other algae, though often masked by other pigments. Much organic debris occurs in such samples; in some the chlorophyll grains themselves are visible, and in others the preservative liquid has become green by solution of the pigment. It may be added that chlorophyll granules become brownish on decomposition and oxidation, and thus may give rise to grey or brown muds. Hence mere colour is no criterion of origin and should not be used as a guide to classification of the deposits. Most of these "green muds" are more adequately described as diatomaceous muds. The samples which do contain glauconite are here termed glauconitic muds in order to indicate their characteristic quality more precisely. The quantity of glauconite is often insufficient to impart a green colour to the sediment, but the presence of the mineral is indicative of peculiar conditions in the sea water.

[1] Neaverson, E., 1928. *Stratigraphical Palaeontology*, p. 100, 8vo, London.

The classification adopted for the Discovery samples may be tabulated as follows:

Table II

Shallow-water deposits, between low water mark and 100 fathoms deep	Gravels	Terrigenous deposits, containing detrital material derived from land masses
	Sands	
	Muds	
Deep-sea deposits, from depths greater than 100 fathoms	Glauconitic mud	
	Diatomaceous mud	
	Diatom ooze	Pelagic deposits, of organic origin, formed outside the range of detritus-bearing currents
	Globigerina ooze	
	Radiolarian ooze	

GENERAL DISTRIBUTION OF THE DEPOSITS

SOUTH ATLANTIC REGION (Plate XVII)

This region is represented by fifty-nine samples from numbered stations as indicated in Table III. In addition, eight samples from other localities (indicated by letters) are included, of which five (A, B, C, D, E) are from stations situated north of the area covered by Plate XVII. The sixty-seven samples may be classified thus:

Table III

Deposit	Locality numbers in Station List	
	R.R.S. 'Discovery'	R.S.S. 'William Scoresby'
Globigerina ooze	A, B, C, D, E, 8, 9, 64, 78, 83, 84, 89	128, 129, 520, 521, 522
Radiolarian ooze	71, 74, 77, 1165	
Diatom ooze	F, G, 10, 11, 12	255, 374, 377, 429
Diatomaceous mud	63, 117, 162, 167, 169, 212	201, 202, 203, 204, 205, 403, 428, 468, 469, 470, 471, 472, 474, 524, 526, 768
Glauconitic mud		433, 518
Terrigenous mud	J	
Sand	160, 235, 236, 237, 363, 366	314, 317, 319, 381, 406, 525

Globigerina OOZE is the most widespread deposit accumulating in the vast region covered by the South Atlantic Ocean, and all the localities here recorded fall within the area shown for *Globigerina* ooze on the map appended to the *Challenger Report*. The majority lie in the main area to the north of lat. 46° S, but four of them appear somewhat isolated in the Discovery records. The most westerly occurrence is at St. 64, to the north-east of the Falkland Islands; the deposit is hardly typical *Globigerina* ooze, but the locality is near the line drawn by Murray west of the South American coast, to separate the ooze from terrigenous deposits; moreover the sample contains grains of glauconite. Three stations, namely, WS 520, WS 521, and WS 522, which lie between the Falkland Islands and South Georgia, between lat. 52° and 53° S, represent the most southerly localities from which *Globigerina* ooze was collected by the Discovery Expeditions. A noteworthy feature at St. WS 522 is the presence of a fair proportion of diatoms among the smaller organisms; but an extensive area occupied by diatom ooze occurs at no great distance to the east. The deposit at St. WS 522 also contains the zeolite mineral phillipsite along with coarse sand grains and occasional pebbles, the latter up to 1 cm. in diameter. Another occurrence of pebbles at an even greater depth in the same area (St. WS 317) is mentioned on p. 304 of this report. In general, *Globigerina* ooze is confined to stations of considerable depth (2000–4600 m. in the present investigation) situated far from land. The occurrence of pebbles in such deposits is therefore an unusual feature; in this instance it seems to be connected with the unusually varied character of the submarine topography.[1]

Radiolarian ooze. Hitherto, no radiolarian ooze has been recorded from the South Atlantic Ocean, but the Discovery Expedition obtained samples of this deposit in the western part of the region from Sts. 71, 74 and 77, at depths of 5460, 5446 and 5186 m. respectively. In an examination of the deposits themselves, Radiolaria are not much in evidence, being obscured by the finer material, but the organisms are very plentiful in coarse washings from the sediments; diatoms and sponge spicules occur in subordinate quantity. Reference to Plate XVII shows that radiolarian ooze must occupy a considerable area in this part of the South Atlantic which was included by Murray and also by Pirie in the belt of *Globigerina* ooze. It may be noted that St. 71 is near the middle of the Argentine Basin.[2] Another sample of radiolarian ooze was obtained at St. 1165 (long. 9° 25·5′ E, lat. 40° 54·7′ S) at a depth of 4642 m.

Diatom ooze. Five samples of diatom ooze were obtained by R.R.S. 'Discovery' along a north-east–south-west line, north-east of South Georgia. The samples from Sts. 10 and 11 are recorded in the Station List as "radiolarian ooze", but Radiolaria are found to be subordinate to diatoms in these deposits. Four stations made by the 'William Scoresby' south-west and west of South Georgia also yield typical diatom ooze. Hence a wide stretch of ocean in this region is marked by the abundance of diatoms and the absence of Foraminifera. The occurrence of diatomaceous deposits here does not conform to Murray's map which includes the area in the belt of *Globigerina* ooze, as does the later map of Pirie.[3] The most westerly of these stations, namely, WS 377 and WS 429, are in approximately 45° W long. This appears to be near the western limit of the diatom ooze, for St. WS 522, in 47° W long. and about the same latitude as St. WS 429, yields *Globigerina* ooze. These stations lie along the line of a submarine ridge which can be traced almost continuously between the Burdwood Bank, south of the Falkland Islands, and the Shag Rocks, west of South Georgia. As Herdman has shown, there appears to be a gap of about 60 miles (long. 47–49° W) where the soundings show greater depths than usual. This depression is occupied by *Globigerina* ooze (Sts. WS 521, WS 522), while the diatom ooze under discussion is accumulating on the eastern slope at a depth of 2549 m. (St. 429). This is about an average depth for the occurrence of diatom ooze, though the deposit is recorded from 5000 m. at St. 11, north-east of South Georgia. The deposit is remarkably uniform in character over the whole region. The genera which occur most constantly are *Coscinodiscus*, *Cocconeis*, *Fragilaria*, *Thalassiothrix* and *Rhizosolenia*, while other forms, such as *Thalassiosira*, *Biddulphia* and *Achnanthes* are occasionally present. There is a minimum of terrigenous material and an entire absence of the perishable organic debris which is so characteristic of diatomaceous muds. Nearer to South Georgia the diatomaceous deposits contain a considerable proportion of terrigenous material evidently transported from the land area; these deposits are assigned to the category next to be described.

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[1] See Herdman, H. F. P., 1932. Report on Soundings, etc. *Discovery Reports*, VI, p. 219 and plate xlv.

[2] See Wüst, G., 1933. Wiss. Ergebn. Deutschen Atlant. Exped. 'Meteor', VI, i, plate viii.

[3] Pirie, J. H. H., 1913. Deep-Sea Deposits of the Scottish National Antarctic Expedition. *Trans. Roy. Soc. Edin.*, XLIX, pp. 645–86.

DIATOMACEOUS MUD. The great majority of the twenty-six stations which yield diatomaceous mud lie in the Scotia Sea, north of the South Shetland and South Orkney Islands. The samples from these stations conform very closely to those from the regions of South Georgia and the South Shetlands, but there is some variation in general constitution. In this connection, the sample from St. WS 204 may be quoted as illustrating gradation from diatomaceous mud to diatom ooze, for it is almost of sufficient purity to be included in the latter category; moreover the perishable part of the organic debris has almost disappeared. The diatomaceous muds occur at greatly varying depth; St. WS 768 yields diatomaceous mud at a depth of 108 m., and a similar deposit occurs at St. WS 201 at a depth of 4134 m. In both deposits some of the mineral grains reach a diameter of 0·5 mm., a size which is surprising at the latter depth. It must be inferred that depth in itself is unimportant compared with distance from land and the influence of detritus-bearing currents. Among the inorganic constituents, quartz and green hornblende are the most abundant and widespread minerals. The presence of a few other minerals, noted incidentally during the general examination of the deposits, may be recorded here, though the significance of their occurrence can only be determined when the mineralogical analysis of all the samples is completed. Well-formed crystals of hypersthene are noted in the samples from Sts. WS 400 and WS 471; this mineral also occurs in samples from the west of the Falkland Islands (p. 305). The presence of glaucophane at St. WS 403 doubtless has some connection with its widespread occurrence at stations in the western part of the Bransfield Strait further south (p. 309). The interesting zeolite-mineral phillipsite recorded from St. WS 470 is of sporadic occurrence and is probably connected with the chemical and physical conditions which determine the decomposition of volcanic rocks on the sea floor. The organic constituents may include Radiolaria and sponge spicules, but diatoms are preponderant. *Coscinodiscus*, *Thalassiosira*, *Fragilaria*, *Cocconeis*, *Rhizosolenia* and *Corethron* are the genera most commonly seen, though from time to time other forms such as *Triceratium*, *Biddulphia* and *Asteromphalus* are noted. Only occasionally are calcareous shells present in these deposits. In samples from Sts. WS 468 and WS 469 tests of *Globigerina* occur, but their broken and worn appearance suggests that they are drifted material. The characters of a sample from Drake Strait (St. WS 403) are less easy to interpret. The coarser fraction contains many tests of *Globigerina* and rotaline Foraminifera together with Radiolaria, but mingled with these are abundant angular sand grains up to 0·1 mm. across; the abundance of the latter prevents classification as an ooze. On the other hand, the finer fraction is mainly of diatomaceous origin; this and the terrigenous matter seem to determine the deposit as a diatomaceous mud, despite the presence of the Foraminifera. St. WS 403 lies within the limits of a belt through Drake Strait considered by Pirie to consist of diatom ooze.

With regard to the sample from Bouvet Island, St. 117 lies well within the belt of diatom ooze as indicated on the maps of Murray and Pirie. Both these observers would doubtless classify the sample as diatom ooze, but they constantly remark that the deposits of this area are not typical diatom ooze.

GLAUCONITIC MUD. Most of the glauconitic deep-sea deposits in the Discovery collection are from the South African region (p. 304), but two stations, far removed from that area, must be considered here. About 80 miles east of the Falkland Islands (Sts. WS 433 and WS 518) glauconitic mud was dredged from depths of 1035 and 1258 m. In each sample grains of glauconite are seen infilling the broken tests of Foraminifera, and the shape of other grains is consistent with formation within such shells. The localities are near the south-western margin of the *Globigerina* ooze belt, and they may be within the overlapping limits of the cold north-flowing Antarctic Drift and the warm south-flowing extension of the Brazil current. The occurrence of glauconite here is therefore in accordance with prevalent theories regarding the conditions under which the mineral is formed.

TERRIGENOUS DEPOSITS. It is only to be expected that sediments of detrital origin do not occur to any great extent in this oceanic region. Twelve stations, however, have yielded samples of terrigenous deposits; eleven of these are classed as sands and one as terrigenous mud. The latter is a rather sandy grey mud obtained at St. J in a depth of 892 m. St. J is about 150 miles north-east of the Falkland Islands, which lie on an extension of the Patagonian continental shelf; the station appears to be situated on the somewhat steep gradient which slopes rapidly to oceanic depths. The deposit is therefore consistent with a situation within the influence of detritus-bearing currents. Even so, the paucity of organic remains is remarkable.

The sands are from widely separated localities, each of which may be discussed separately. Sts. 235, 236 and 237 to the north-east of the Falkland Islands have yielded sands from depths of 600, 612, and 904 m. respectively. Evidently these stations lie on an easy gradient which continues northwards to about lat. 47°, where it begins to slope more rapidly to oceanic depths. The occurrence of these sands is consistent with north-flowing currents bearing detritus from the Falkland Islands area.

The samples from St. WS 317 and WS 319 appear to be incomplete; indeed the record of the latter sample in the Station List bears a note, "finer material from bottom sample washed out". The presence of small pebbles, however, at depths of 3369 and 1602 m. is unexpected, especially as the former locality is within the belt of *Globigerina* ooze. In view of the uncertainty as to the constitution of these samples, the deposits are not shown on the accompanying map.

St. WS 406, on the northern side of Drake Strait, yields a foraminiferal sand from a depth of 1234 m. The proportion of sand grains forbids reference to this deposit as an ooze, though Pirie postulates a belt of *Globigerina* ooze through Drake Strait. It may be recalled that the same difficulty occurs with regard to a sample from St. WS 403 farther south, which is tentatively classified as diatomaceous mud (p. 303).

A clean coarse sand from St. 381, just west of Elephant Island in the South Shetlands, at a depth of 425 m., is noteworthy for the presence of garnet among the detrital minerals.

Two samples of sand from the South Sandwich Islands (Sts. 363 and 366) are remarkable for the abundant fragments of vesicular volcanic glass, the angularity and freshness of which proclaim their local origin. These stations, with depths of 329 and 340 m., lie on the eastern part of an arcuate submarine ridge which connects South Georgia with the South Orkney Islands, and includes the South Sandwich group. The latter islands are recorded[1] as volcanic centres, and doubtless the sands are formed by the denudation of the eruptive material.

The two remaining sands are from Sts. 160 and WS 314, in the neighbourhood of the Shag Rocks, west of South Georgia, at depths of 177 and 137 m. respectively. The most interesting feature is the presence at St. WS 314 of colourless flakes some of which show hexagonal outlines; the radial texture of many suggests that they are zeolitic aggregates formed by the decomposition of volcanic rock.

THE WEST AND SOUTH COASTS OF AFRICA (Plate XVII inset)

Seventeen stations, namely Sts. K, L, M, 89, 93, 94, 95, 96, 97, 98, 101, 102, 263, 264, 265, 283 and 425, are grouped in this area. The most northerly station (283) off Annobon in the Gulf of Guinea is outside the limits of Plate XVII. The sample is a fairly coarse foraminiferal sand, containing very few mineral grains; the depth is recorded as 18–30 m.

The remaining samples were collected off the south and south-west coasts of Africa. The stations are shown on Plate XVII (inset), with the exception of the isolated St. 425, south-east of Port Elizabeth, which is outside the eastern limit of the map. The samples from the stations nearest land (Sts. 93, 94, 95, 96, 97, 263, 264, 265) contain the mineral glauconite, though this constituent is not abundant in any of them. It generally occurs in rounded grains, some of which are compound or lobate. In some samples (e.g. St. 96) the glauconite is seen infilling the chambers of broken *Globigerina* shells. These foraminiferal tests are so abundant at Sts. 95, 96 and 97 that the samples might almost be described as *Globigerina* ooze; but they contain a fair proportion of mineral grains, and the presence of glauconite gives a distinct character to the deposit. Glauconitic mud is accumulating at depths of 165 to nearly 1000 m., to a distance of some 60 miles from the coast, while the Agulhas Bank, long famed for glauconitic deposits, lies at no great distance to the south-east. Farther west, at Sts. 89, 98, 101 and 102, typical *Globigerina* ooze with only occasional mineral grains occurs at depths of 3926, 3640, 3734 and 1800 m. respectively.

---

[1] Douglas, G. W., and Campbell Smith, W., 1930. Zavodovski Island, and notes on Rock Fragments dredged in the Weddell Sea. *Quest Report*, p. 63. Kemp, S., and Nelson, A. L., 1931. The South Sandwich Islands. *Discovery Reports*, III, p. 150.

THE FALKLAND ISLANDS (Plate XVIII)

The twenty-eight samples from this region are of very uniform character. Most of them are sands composed essentially of terrigenous material. The depth is slight, varying in different parts of the area between 23 and 251 m.; and the region is universally accepted as forming part of the South American continental shelf.

Recently, these sands have been classified by L. H. Matthews[1] on the basis of mechanical analysis, with the object of providing data concerning the habitats of the organisms which live on them. Geologically, the chief interest of these deposits lies in their mineral content, but as this will be fully discussed in a future report, only a brief reference to minerals of common occurrence need be given here. Like the majority of sands, these contain a preponderance of quartz grains, and this feature may be correlated with the wide distribution of sandstones and quartzitic rocks in West Falkland Island and the north part of East Falkland Island.[2] The outstanding point of interest is the abundance, in most of the samples, of well-formed (but worn) crystals of hypersthene, a mineral which is characteristic of the andesitic volcanic rocks of South America. The sample from St. 48 yields rounded grains of red garnet and brown tourmaline in addition to hypersthene. Foraminifera occur plentifully in some of the samples, and diatoms are also present, either alone or associated with the Foraminifera.

South of the Falkland Islands, between lat. 54° and 55° S and long. 56° and 62° W, is the Burdwood Bank, which is separated from the Falklands by comparatively deep water. Two samples (Sts. WS 86 and WS 87) are available from the Burdwood Bank at depths of 151 and 96 m. respectively. They consist of sandy deposits with a varied assortment of shelly material including an abundance of Foraminifera. A sample from the eastern portion of this bank, obtained by the Scotia Expedition (1903), has been described by Pirie,[3] and the station was included by him in the belt of *Globigerina* ooze. This, however, is hardly justified by his description of the deposit, as the Foraminifera are said to be of shallow-water Antarctic types. The abundance of terrigenous material in the deposits, considered in conjunction with the soundings,[4] shows that the Burdwood

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[1] Matthews, L. H., 1934. The Marine Deposits of the Patagonian Continental Shelf. *Discovery Reports*, IX, pp. 175–206.

[2] Baker, H. A., 1923. *Final Report on Geological Investigations in the Falkland Islands* (1920–1922), Fol. London.

[3] Pirie, J. H. H., 1913. Deep-Sea Deposits of the Scottish National Antarctic Expedition. *Trans. Roy. Soc. Edin.*, XLIX, pp. 645–86.

[4] Herdman, H. F. P., 1932. Report on Soundings, etc. *Discovery Reports*, VI, pp. 205–36.

Bank belongs to the shallow seas of the continental shelf. It may be noted that fragments of shale from St. WS 87 have been examined and described by W. A. Macfayden,[1] who deduces a Cretaceous age for the shale from the evidence of Foraminifera contained therein. He also suggests, from the abundance of shale pebbles in the dredgings, that the beds must outcrop on the sea-bottom at or close to the stations. Some of the shale fragments are highly glauconitic, grains of this mineral being prominently exposed on the worn surfaces. It follows that some (at least) of the glauconite grains present in the modern deposit are "derived" by disintegration of the shale.

Two stations (228 and 230) are situated in the depression between the Falkland Islands and Burdwood Bank, where depths of 660 and 675 m. are recorded. The first-named station yields a diatomaceous mud which is similar in general constitution to the great majority of such deposits from the Scotia Sea. The deposit from St. 230 is classed as terrigenous mud because of the abundance of detrital mineral grains and the absence of recognizable organic remains. This procedure, though unavoidable, is somewhat unsatisfactory, for it leaves out of account the considerable proportion of flocculent material which contributes largely to the bulk of the deposit. It is undoubtedly of organic origin but is so indefinite that its precise nature cannot be determined. But from the geological standpoint the omission is not so serious; for when thoroughly dried, the flocculent material shrinks to a mere film round the detrital grains, and the deposit eventually approaches the type exemplified by the marine silts of the English Fenland.

SOUTH GEORGIA (Plate XIX)

From this region the 'Discovery' collected twenty-three samples, while a further twenty-one were obtained by the 'William Scoresby'. The majority of the forty-five samples are of very uniform character, falling within the group classified in this report as diatomaceous mud.

Judging by the records of soundings, South Georgia is surrounded by a belt of shallow sea, varying from 20 to 300 m. in depth. Outside this area, usually at about 30 or 40 miles from the island, the depth increases rapidly to 1000 m. and more. This variation in depth appears to have little (if any) influence on the character of the deposits, for diatomaceous mud from Sts. 129 (depth 1001 m.), 151 (depth 3200 m.), WS 26 (depth 1180 m.) and WS 63 (depth 1752 m.), are essentially similar to diatomaceous mud from stations close inshore. The finer fraction consists mainly of diatoms, with sponge spicules and Radiolaria in subordinate quantity. Mineral grains are present in conspicuous proportion, and the size of the grains appears not to be related to depth alone. For, at St. 129 the largest grains noted are about 0·1 mm. across, whereas at St. 151 grains reaching 0·2 mm. in diameter were noted, though the depth is three times that of the former locality. Green hornblende occurs in several of the samples, particularly those from the more southerly stations. The relative abundance of this mineral in deposits from the mouth of Drygalski Fjord, at the south-east of the island, is probably to be explained by the recorded[1] occurrence of igneous rocks such as gabbro and diorite on the adjacent mainland. At the more northerly stations the mineral seems to be less plentiful. Of the diatoms, *Coscinodiscus*, *Thalassiosira* and *Fragilaria* are the genera most frequently seen; *Rhizosolenia*, so abundant in samples from the Scotia Sea, is relatively scarce.

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[1] Macfayden, W. S., 1933. Fossil Foraminifera from the Burdwood Bank and their geological significance. *Discovery Reports*, VII, pp. 1–16.

The sample from St. 136 differs from all the others in containing deep green glauconite among the abundant mineral grains. Some of this green material is also seen infilling the central canal of sponge spicules. The finer constituent of the deposit consists almost entirely of diatom frustules, along with some sponge spicules. The apparent absence of calcareous material is noteworthy in view of the presence of glauconite, for in other instances calcareous shelly material is constantly seen in association with this mineral.

The remaining three samples, from Sts. 28, 29 and 30 in West Cumberland Bay, are classified as terrigenous mud. The material is exceedingly fine-grained, and recognizable organic debris is restricted to occasional centric diatoms, though oil globules are commonly seen. The deposit, apart from the diatoms, is strikingly similar to sedimentary material from the estuary of the River Mersey, and from the shores of the bay known as the Wash, in England.

THE SOUTH SHETLANDS (Plate XX)

This region is conveniently subdivided into two, (*a*) the Bransfield Strait, (*b*) the Palmer Archipelago, represented by forty-two and fifteen samples respectively. The stations are as follows:

Table IV

	Locality numbers in Station List	
	R.R.S. 'Discovery'	R.S.S. 'William Scoresby'
Bransfield Strait	171, 172, 175, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 206, 209, N	382, 383, 384, 385, 386, 387, 388, 389, 391, 392, 393, 394, 475, 476, 477, 479, 480, 481, 482, 483, 484, 485, 486, 487, 493
Palmer Archipelago	180, 185, 187, 191, 192, O	395, 396, 397, 399, 488, 489, 490, 494A, 494B

Two outlying stations (211, WS 400) to the north-west, also fall within the area of the chart.

(*a*) Bransfield Strait, between the South Shetlands and the northern part of Graham Land, has its greatest recorded depth (about 2000 m.) near its north-eastern outlet. From this end of the strait, between King George Island and Trinity Peninsula, twenty-one samples are described, of which fifteen are diatomaceous muds, four are terrigenous muds, and two are classed as sands. One of the latter (St. 195) is from a depth of 391 m. in Admiralty Bay, King George Island, and the other (St. WS 481) is from a depth of 453 m. on the Graham Land shelf, east of Astrolabe Island. The samples of terrigenous mud are from Sts. 196, WS 312, WS 476 and WS 477, south of Martin's Head, King George Island, at depths which vary from 425 to 1892 m. Most of the samples of diatomaceous mud are from the centre of the depression, where the depth varies between 446 m. towards the south of the traverse and 2085 m. south of King George Island. While the distribution of terrigenous and diatomaceous muds appears to accord generally with depth, there are records which invite further discussion. South of King George Island terrigenous mud occurs at unusual depths for this deposit, but the location is at no great distance from the land surface, which slopes down under the sea with a steep gradient. On the southern side of the Strait the sea-floor falls away quite gently from the land, so that the depth contour of 250 m. lies some 25 miles from the coast of Trinity Peninsula. Thus the occurrence of diatomaceous mud at the slight depth of 345 m. in this part of the strait is explained. But the presence of a similar deposit at a depth of 152 m. close to the northern coast of Trinity Peninsula (St. WS 482) seems to demand conditions, perhaps peculiar to the locality, which are not apparent from the records.

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[1] Tyrrell, G. W., 1930. The Petrography and Geology of South Georgia. *Quest Report*, pp. 28–34.

A further series of twenty-one samples is available from the western part of Bransfield Strait. Here the depression is more shallow and the deposits contain a larger proportion of detrital material. Fourteen samples of diatomaceous mud are from the deeper parts of the sea-floor (800–1000 m.), but towards the south the gentle slope of the bottom allows accumulation of such material at depths of 200–300 m. Terrigenous deposits, containing numerous fragments of volcanic glass, are forming at Sts. 172, 209, WS 394 and WS 493 near Deception Island at depths of 168–500 m. The abundance of volcanic detritus here is only to be expected from Andersson's description of the active volcano which forms Deception Island,[1] "a large crater island, 15–19 km. in diameter. The crater itself forms a basin, 9–10 km. in width and connected with the ocean by a very narrow entrance, only about 200 m. wide". Farther south, at St. 175, a sandy deposit at a depth of 200 m. supports Herdman's[2] suggestion that "there appears to be a ridge between Deception and Tower Islands". Again, sandy material appears at St. WS 389, west of Astrolabe Island at a depth of 130 m.; this station is on the coastal shelf of Graham Land.

(*b*) The Palmer Archipelago is separated from Graham Land by the narrow Gerlache Strait, with an average depth of 600–700 m., which continues westwards by the shallower Bismarck Strait to the Bellingshausen Sea. Five samples of the sea-floor along this line consist of diatomaceous mud, while terrigenous mud occurs at a depth of 300 m. in Schollaert Channel between Anvers Island and Brabant Island. North of the last-named island, between it and Low Island, is a wide and shallow depression from

[1] Andersson, J. G., 1906. The Geology of Graham Land. *Bull. Geol. Inst. Upsala*, VII, p. 49.

[2] Herdman, H. F. P., 1932. Report on Soundings, etc. *Discovery Reports*, VI, p. 231.

which six samples are available. Three stations in the centre of the depression, namely Sts. WS 395, WS 396 and WS 489, yield samples of diatomaceous mud at depths of 297, 318, and 308 m. respectively. On the southern slope of the depression (St. WS 488) terrigenous mud occurs at a depth of 220 m., while the samples from the northern slope (Sts. WS 397 and WS 490) are sands from depths of 150 and 262 m. Incidentally, another sandy deposit occurs at St. WS 399 at a depth of 738 m. on the submarine extension of the South Shetland ridge. Farther east, between Deception Island and the Palmer Archipelago (Sts. WS 494A and WS 494B) sands occur at depths of 1081 and 505 m. respectively. These stations are on either side of a channel between Deception Island and Trinity Island, which connects with the open ocean to the north-west. Herdman states that southward-flowing warm water enters this channel between Smith and Snow Islands and passes south of Deception Island into the larger basin of Bransfield Strait. The transport of detrital material by such a current would account for the accumulation of sandy material in this area, especially if the existence of a ridge south of Deception Island be substantiated.

An outstanding feature of these deposits from the western part of the South Shetland region is the occurrence of glaucophane among the detrital minerals. It is most abundant in samples from Sts. WS 396 and WS 489, and it occurs in less quantity in samples from Sts. WS 395 and WS 488 to the south, Sts. WS 494A and WS 494B to the east, and Sts. WS 397, WS 490 and WS 399 to the north, while it has also been detected in a sample from the Scotia Sea much farther north. The provenance of this mineral has yet to be determined, but the size and distribution of the grains suggests that there may be a current flowing eastward between Low Island and Brabant Island in addition to the current already suggested by Herdman between Smith and Snow Islands.

The diatomaceous muds of the South Shetlands region partake of the general characters described on p. 299. They are generally greenish muds with a considerable proportion of flocculent material enclosing the detrital sand grains. The genera *Coscinodiscus*, *Fragilaria* and *Cocconeis* are most constantly present, as they occur in nearly every sample examined. At some stations the predominance of these genera is rivalled by *Corethron* and *Rhizosolenia*, which are especially well developed and abundant in the sample from St. WS 384, for example. Other genera noted in many samples include *Thalassiosira*, *Triceratium*, *Biddulphia* and *Thalassiothrix*, and probably a critical examination of the diatom assemblages would reveal the presence of others.

THE BELLINGSHAUSEN SEA (Plate XXI)

This region is represented by samples from twenty-one stations. The most northerly locality (St. WS 501), in Bismarck Strait south of Anvers Island, yields diatomaceous mud at a depth of 583 m. The deposit is very similar to the diatomaceous mud which is widely distributed in the Scotia Sea. In the shallower waters around the Biscoe Islands (Sts. WS 498, WS 499) terrigenous material predominates, though diatom debris still contributes largely to the bulk of the sediments.

Farther to the south-west a series of eleven soundings taken along a north-west traverse from Adelaide Island shows that the continental shelf extends some 80 miles from the coast, and that the edge of the shelf is very steep, the depth increasing from 500 to 3000 m. in 15 miles. A profile section (adapted from Herdman[1]) is shown on Plate XXI. On the shelf the deposits from Sts. WS 509–515 have all the characteristics of diatomaceous mud, and the assemblage of diatoms is similar to that seen in samples from the Scotia Sea. Near the edge of the shelf (St. WS 516), at a depth of 2611 m., the bulk of the deposit is a coarse sand containing angular grains of quartz and opaque fragments of rock. Farther to the north-west (St. WS 517) the detrital grains are of smaller size, and the organic remains become more important so that the deposit must be classified as diatomaceous mud. The presence of coarse sand at so great a depth on the continental slope, and at so great a distance from land, raises interesting questions as to the cause of its occurrence. But speculation must remain in abeyance for the present, as no other sample from a similar situation is available and generalization is hardly possible on a single example.

The remaining seven samples are from stations farther south and west, as far as lat. 70° S and long. 100° W. St. WS 495, north-west of Alexander I Island, yields diatomaceous mud of the usual type at a depth of 2582 m. At St. WS 508 the deposit (taken from a depth of 309 m.) is a coarse sand or fine gravel which may indicate a bottom of bare rock. The samples from Sts. WS 506 and WS 507 at a depth of about 580 m. can only be classified as terrigenous mud; for though flocculent material appears as conspicuous as the small mineral grains enclosed therein, there are few recognizable organisms. The same brown unctuous mud occurs farther west at greater depths, namely at Sts. WS 505 (1500 m.) and WS 503 (4073 m.); it is probably typical of the sea-floor in these high latitudes, for Herdman states that "the average depth of the ocean bed in the Bellingshausen Sea varies very little", the average depth being approximately between 3900 and 4400 m. A brown mud from a depth of 4334 m. at St. WS 502, however, is classified as diatomaceous mud, because recognizable diatoms are present in some quantity, and their occurrence seems to account for the (presumably organic) flocculent material. But the abundance of terrigenous material at these great depths and at so great a distance from land is surprising, and seems to demand some special means of transport. It may be that much detrital material has been contributed by the melting of icebergs, as Pirie[2] has suggested for the muddy deposits of the Weddell Sea.

THE WESTERN COAST OF SOUTH AMERICA (Plate XXII)

Samples of sea-floor deposits are available from fifty-one stations off the western coast of South America, between the equator and lat. 40° S, along the course of the Humboldt current. The majority of the samples are remarkably uniform in character, thirty-six being classified as diatomaceous mud, eight as terrigenous mud and eight as sand. The first-named deposit has much the same general constitution as its equivalent in the Scotia Sea, containing a considerable proportion both of mineral grains and of flocculent diatom debris; the latter is usually sufficient in quantity to impart a green colour to the mud. In the South American samples, however, the flocculent aggregates constantly enclose numerous brown resting spores which presumably belong to various algae; moreover similar spores are often seen in position within the frustules of *Coscinodiscus* and other diatoms. While this peculiarity is undoubtedly of a seasonal character, it tends to support the previously formed conclusion that the flocculent material is largely formed of the disorganized cell contents of algae. It is worthy of note, too, that the assemblage of diatoms in the deposits under discussion differs considerably from that found in the samples from the Scotia Sea. *Coscinodiscus* is the predominant genus in both regions, and it is particularly large and abundant in most samples from South American waters. Here it is constantly accompanied by *Actinoptychus* and *Navicula*, while *Asteromphalus*, *Bacteriastrum*, *Entopyla*, *Grammatophora*, *Pleurosigma*, *Licmophora*, *Chaetoceros* and *Triceratium* are more sporadic in occurrence. Many of these genera have not been observed in the deposits from the Scotia Sea during the present investigation. There (it may be recalled) *Thalassiosira*, *Fragilaria*, *Rhizosolenia* and *Corethron* are (after *Coscinodiscus*) most consistent in occurrence, but these genera are virtually absent from the South American assemblages. Another feature of minor interest is the presence of the widespread silicoflagellate *Dictyocha fibula*, Ehr., in several of the South American samples.

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[1] Herdman, 1932. Report on Soundings, etc. *Discovery Reports*, VI, p. 228.

[2] Pirie, J. H. H., 1914. Deep-Sea Deposits of the Scottish National Antarctic Expedition. *Trans. Roy. Soc. Edin.*, XLIX, p. 677.

As in other regions, the accumulation of diatomaceous mud shows little relation to depth, for such deposits are found at the slight depth of 29 m. (St. WS 676), while they are also present at depths of over 4000 m. (Sts. WS 686, WS 703–705). This bathymetrical range is similar to that shown by the terrigenous mud which occurs in a depth of 369 m. at St. WS 396, and at St. WS 617 in 4864 m. It must be noted, however, that some of these deposits differ from diatomaceous mud only in the proportion of flocculent matter and in the paucity of recognizable organic remains. In any case, the great vertical range of terrigenous material seems to be due to the circumstance that the continental shelf is very narrow along the western coast of South America, with the consequence that areas of considerable depth are within the range of currents which transport detritus from the land surface. The irregular distribution of diatoms and other organisms is probably due to local differences in chemical and physical conditions.

The mineral content of the diatomaceous muds is, in general, similar to the detrital material which makes up the bulk of the terrigenous deposits. Quartz is the most abundant mineral and accounts for the bulk of the detrital grains in all the deposits. Green hornblende also is of widespread distribution, having been noted in thirty-five of the fifty-two samples, but brown hornblende is apparently rarer and of sporadic occurrence. Hypersthene is noted only occasionally in these South American deposits at three stations (WS 591, WS 596, WS 604) between 32° and 36° S lat. though volcanic glass occurs in about half the samples. The presence of plagioclase felspar at three stations probably indicates that the mineral has not always been distinguished by the writer from other colourless grains; complete mineralogical analysis of the samples will probably reveal a wider distribution than is shown in the present record. Among other minerals, white mica is noted at five stations (WS 604, WS 615, WS 617, WS 692 and WS 697), tourmaline at one locality (St. WS 697) and a yellow mineral which appears to be staurolite at Sts. WS 604 and WS 605; the last record, however, needs confirmation. Finally, the authigenic mineral phillipsite is recorded from two stations (WS 602 and WS 650) which are separated by a considerable distance, at depths of 75 and 143 m. respectively. The occurrence of phillipsite at such slight depth is unusual, judging by Murray's statement that "it always occurs in the deeper deposits", but the mineral appears to have a longer bathymetrical range than that recorded in the literature.

Grateful acknowledgment is made of assistance during the course of this investigation. The writer has had much helpful discussion with Professor P. G. H. Boswell of the Royal School of Mines, London, under whose direction the work has been done. Conversation with colleagues in the University of Liverpool has served to elucidate many obscure details, while Dr Stanley Kemp and his staff have always been ready to give information in amplification of the published records. The charts have been drawn by Miss E. C. Humphreys.

DESCRIPTIONS OF THE SAMPLES

R.R.S. 'DISCOVERY'

Station **A**. 29. ix. 25. Lat. 47° 34′ N. Long. 8° 20′ W. 4287 m.
Globigerina ooze. A greyish white mud composed of *Globigerina* fragments; unbroken tests are rather scarce. The finer fraction is extremely fine-grained and contains coccoliths in abundance. Only occasional mineral grains are seen.

Station **B**. 16. x. 25. Lat. 29° 56′ 50″ N. Long. 15° 03′ 10″ W. 3400 m.
Globigerina ooze. Similar in all respects to sample from Station A.

Station **C**. 26. xi. 25. Lat. 22° 32′ 15″ S. Long. 16° 40′ 10″ W. 4330 m.
Globigerina ooze. Similar to foregoing samples, but coccoliths and rhabdoliths in the finer fraction are perhaps even more in evidence. No mineral grains seen.

Station **D**. 30. ix. 25. Lat. 26° 07′ 40″ S. Long. 14° 36′ 20″ W. 3195 m.
Globigerina ooze. A light brown, coherent, granular deposit. Coarse washings consist principally of foraminiferal shells of the genera *Orbulina*, *Globigerina* and *Pulvinulina*, with a few fragments of echinid spines. Fine washings contain mainly minute particles, which include coccoliths and rhabdoliths.

Station **E**. 30. xi. 25. Lat. 26° 17′ 40″ S. Long. 14° 36′ 20″ W. 3170 m.
Globigerina ooze. Greyish white in colour: foraminiferal tests mostly fragmentary. Coccoliths and rhabdoliths both plentiful in the finer material.

Station **F**. 19. ii. 26. Lat. 53° 00′ S. Long. 34° 22′ 30″ W. 2472 m. (Plate XVII.)
Diatom ooze. A typical and pure diatom ooze, with occasional Radiolaria and a few detrital mineral grains. The genera *Coscinodiscus*, *Thalassiosira*, *Fragilaria*, *Achnanthes*, *Rhizosolenia* and *Thalassiothrix* are noted.

Station **G.** 19. ii. 26. Lat. 52° 54′ S. Long. 34° 05′ W. 3469 m. (Plate XVII.)

DIATOM OOZE. A whitish, coherent, powdery sediment, made up entirely of diatom frustules, among which large centric forms such as *Coscinodiscus* and *Thalassiosira* are most conspicuous; other forms include navicular and elongate genera, e.g. *Fragilaria*, *Achnanthes*, *Thalassiothrix* and *Rhizosolenia*.

Station **H.** 2. iii. 26. East Cumberland Bay, South Georgia. Lat. 54° 15′ 15″ S. Long. 36° 32′ W. 229–256 m. (Plate XIX, inset.)

DIATOMACEOUS MUD. A grey fine-grained mud, mainly composed of angular to subangular mineral grains of extremely small size. Some fragments of quartz, however, are more than 0·1 mm. across. Some centric diatoms (*Coscinodiscus*) are present; they are usually rather small but some reach 0·1 mm. in diameter.

Station **I.** April 1926. Off Cumberland Bay, South Georgia. 183 m.

DIATOMACEOUS MUD. The deposit contains abundant mineral fragments (quartz and green hornblende); a few reach 0·2 mm. in diameter but the majority are smaller. Fine-grained flocculent material contains centric diatoms (chiefly *Coscinodiscus*), many of which retain their greenish protoplasmic contents; finer particles may be comminuted diatom tests. The greenish colour of the deposit is apparently due to chlorophyll, for the preservative liquid is coloured green.

Station **J.** 21. v. 26. Lat. 49° 32′ 30″ S. Long. 55° 28′ 30″ W. 892 m. (Plate XVII.)

TERRIGENOUS MUD. This rather sandy grey mud consists mainly of mineral grains among which some reach a diameter of 0·2 mm., but most are below diameter of 0·05 mm. Grains of quartz and green hornblende are abundant. There is some admixture of diatoms and sponge spicules.

Station **K.** 25. ix. 26. Lat. 33° 05′ S. Long. 16° 18′ E. 3260 m. (Plate XVII, inset.)

GLOBIGERINA OOZE of same type as foregoing samples. The finer material consists largely of comminuted foraminiferal shells, coccoliths and rhabdoliths.

Station **L.** 28. ix. 26. Lat. 33° 19′ S. Long. 17° 40′ E. 235 m. (Plate XVII, inset.)

GLAUCONITIC MUD. This is a detrital sediment consisting mainly of clean quartz grains, apparently evenly graded at a diameter of about 0·05 mm. Some glauconite is present as dark green grains while dark opaque grains, slightly larger, occur in some abundance. Flocculent matter also occurs.

Station **M.** 29. ix. 26. Lat. 33° 21′ S. Long. 16° 47′ E. 2020 m. (Plate XVII, inset.)

GLOBIGERINA OOZE. Mainly broken tests of *Globigerina*. Little detrital matter if any. Shields of calcareous flagellates (especially coccoliths) are plentiful among the finer particles.

Station **N.** 26. ii. 27. Lat. 62° 57′ S. Long. 60° 21′ 30″ W. 967 m. (Plate XX.)

DIATOMACEOUS MUD. The sample consists mainly of greenish flocculent material which is apparently diatomaceous in origin. Besides frustules of *Rhizosolenia*, *Fragilaria* and *Coscinodiscus* it contains small sand grains with a diameter of usually less than 0·05 mm., among which quartz and volcanic glass are noted.

Station **O.** 19. iii. 27. Lat. 64° 56′ S. Long. 64° 43′ W. 435 m. (Plate XX.)

DIATOMACEOUS MUD. A light grey mud with abundant grains of quartz and green hornblende; some of the grains are 0·5 mm. across, but the majority are less than 0·05 mm. in diameter. Organic remains form a subordinate proportion of the sample; they are mainly broken diatom tests (but some whole frustules of *Coscinodiscus*) and sponge spicules.

Station **P.** 21. xii. 26. Drygalski Fjord, South Georgia; about 1–1½ miles from glacier at end of fjord. 178·3 m. (Plate XIX.)

DIATOMACEOUS MUD. A greyish mud, containing roughly equal proportions of small sand grains and flocculent material. The sand grains, generally less than 0·05 mm. in diameter, are mainly fragments of quartz, but green hornblende is also plentiful. The flocculent matter is largely diatomaceous; there are some unbroken centric frustules.

Station **8**. 9. ii. 26. Lat. 42° 36′ 30° S. Long. 18° 19′ 30″ W. 3450 m. (Plate XVII.)

Globigerina ooze. Light grey, coherent and granular. The larger constituents are mainly shells of *Globigerina*, up to 0·2 mm. in diameter. Finer particles extremely small, chiefly coccoliths, some of which occur in groups; rhabdoliths seem to be scarcer.

Station **9**. 11. ii. 26. Lat. 46° 09′ S. Long. 22° 26′ W. 2226 m. (Plate XVII.)

Globigerina ooze. Brownish, coherent and granular. Coarser material consists of broken *Globigerina* tests, with a few mineral grains. The finer particles consist largely of coccoliths in some variety; a few more or less complete coccospheres are noted.

Station **10**. 13. ii. 26. Lat. 46° 35′ S. Long. 24° 15′ 30″ W. 4402 m. (Plate XVII.)

Diatom ooze. A grey-brown, coherent mud. The bulk of the deposit is formed of diatom frustules among which large centric forms (*Coscinodiscus*) are conspicuous; navicular and elongate forms, including *Fragilaria*, *Achnanthes*, *Rhizosolenia* and *Thalassiothrix*, are also present. There is much comminuted material, together with some detrital minerals and occasional nasselarian Radiolaria. The presence of the last-named probably accounts for the description of this sample as "radiolarian ooze" in the official Station List, but the deposit is undoubtedly diatom ooze.

Station **11**. 16. ii. 26. Lat. 50° 26′ S. Long. 30° 27′ W. 5000 m. (Plate XVII.)

Diatom ooze. A grey-brown coherent sediment, becoming light grey on drying. The bulk of the sample consists of the usual diatom assemblage in which frustules of *Coscinodiscus*, *Biddulphia*, *Achnanthes*, *Fragilaria*, *Rhizosolenia* and *Thalassiothrix* are prominent, with a few nasselarian Radiolaria. Some small, angular quartz grains (up to 0·1 mm. diameter) and fragments of green hornblende are present, but the sample is too small for mineral analysis.

Station **12**. 18. ii. 26. Lat. 51° 55′ 05″ S. Long. 11° 44′ W. 2744 m. (Plate XVII.)

Diatom ooze. A grey, powdery sediment containing a variety of diatoms, including *Coscinodiscus*, *Fragilaria*, *Rhizosolenia*, *Achnanthes*, *Thalassiothrix* and *Biddulphia*, with some sponge spicules and small mineral grains.

Station **13**. 3. iii. 26. 5·7 miles N 49½° E of Jason Light, South Georgia. 143 m. (Plate XIX, inset.)

Diatomaceous mud. A greenish grey "buttery" clay. The bulk of the deposit consists of mineral grains, usually very small, but quartz grains occasionally reach a diameter of 0·2 mm., and prisms of green hornblende a length of 0·05 mm. Much comminuted diatom material is present as well as recognizable centric and navicular diatoms and sponge spicules.

Station **14**. 3. iii. 26. 15·4 miles N 44½° E of Jason Light, South Georgia. 260 m. (Plate XIX, inset.)

Diatomaceous mud. The deposit has a "buttery" consistency and is mainly composed of finely comminuted diatom material. Some frustules of *Coscinodiscus* are large, but most are less than 0·1 mm. across; tests of *Fragilaria* and *Thalassiothrix*, as well as sponge spicules are present. Some rounded quartz grains reach a diameter of 0·2 mm., but the average is below 0·05 mm. Grains of brown hornblende are about 0·05 mm. long. There is apparently no mineral to account for the greenish hue of the mud, which may be due to a vegetable pigment such as chlorophyll.

Station **15**. 3. iii. 26. 25 miles N 45½° E of Jason Light, South Georgia. 191 m. (Plate XIX, inset.)

Diatomaceous mud. Similar to samples from Sts. 13 and 14; mineral grains reach 0·1 mm. in diameter.

Station **16**. 3. iii. 26. 36·5 miles N 46° E of Jason Light, South Georgia. 727 m. (Plate XIX.)

Diatomaceous mud. The sediment has separated into layers during storage, dark grey below, light brown above. The finer particles are mainly diatoms, *Coscinodiscus* and *Fragilaria* being conspicuous forms; sponge spicules and fragments of Radiolaria are also present. Quartz grains are abundant and large, many being over 0·1 mm. in diameter; they are angular to subangular in shape. Grains of green and brown hornblende (0·1 mm.) and occasional splinters of volcanic glass are noted.

Station **19**. 4. iii. 26. 10 miles N 39° E of Cape Saunders, South Georgia. 200 m. (Plate XIX, inset.)

DIATOMACEOUS MUD. This dark, greenish sandy sediment approaches a diatom ooze in the abundance of diatoms. *Coscinodiscus* is the most conspicuous genus, but valves of *Fragilaria* are also present with occasional sponge spicules and radiolarian fragments. Quartz grains reach 0·2 mm. in diameter, and prisms of green hornblende 0·15 mm. in length, but most of the grains are smaller. Some amount of greenish flocculent material is present.

Station **20**. 4. iii. 26. 14·6 miles N 41° E of Cape Saunders, South Georgia. 210 m. (Plate XIX, inset.)

DIATOMACEOUS MUD. This sediment is fine-grained and greenish grey in colour. The bulk of the sample consists of diatoms (*Coscinodiscus*, *Fragilaria* and other forms) and exceedingly fine particles of comminuted diatoms. Mineral grains include quartz (up to 0·2 mm., abundant) and green hornblende (0·1 mm.). Sponge spicules also occur. The greenish colour of the sediment is probably due to chlorophyll or other pigment of the diatoms, for the preservative liquid has acquired a green colour.

Station **23**. 14. iii. 26. 5·3 miles N 44° E of Merton Rock, South Georgia. 228 m. (Plate XIX, inset.)

DIATOMACEOUS MUD. This greenish grey "buttery" deposit contains much detrital material, chiefly subangular quartz grains which range down from a diameter of about 0·05 mm. to exceedingly small particles. Flakes of white mica, however, attain a diameter up to 0·1 mm. The organic material is chiefly diatomaceous. Frustules of *Coscinodiscus* are large and abundant; they are accompanied by *Fragilaria*, *Thalassiosira* and other forms. Some sponge spicules are noted. The greenish hue is thought to be due to vegetable pigments.

Station **28**. 16. iii. 26. West Cumberland Bay, South Georgia. 3·3 miles S 45° W of Jason Light. Two samples from depths of 65 and 168 m. respectively. (Plate XIX, inset.)

TERRIGENOUS MUD. (*a*) The sample from 65 m. is a grey mud formed of exceedingly fine mineral particles which react to polarized light. There is a fair quantity of subangular detrital grains and centric diatoms which reach a diameter of 0·1 mm.

(*b*) The sample from 168 m. is a black mud, microscopically similar to sample (*a*), but yellow oil globules are commonly seen. Apart from the diatoms the material is remarkably like some of the black muds of the Mersey estuary in England.

Station **29**. 16. iii. 26. West Cumberland Bay, South Georgia. 5·9 miles S 51° W of Jason Light. 23 m. (Plate XIX, inset.)

TERRIGENOUS MUD. A sediment of "buttery" consistency. The top layers of the sample have oxidized slightly, giving a yellowish tinge. Though some particles reach a diameter of 0·1 mm., the bulk of the material is extremely fine-grained, most of the particles being below 0·01 mm. in diameter. Some of the fine particles react to polarized light, others appear not to do so. No organic material was recognized definitely.

Station **30**. 16. iii. 26. West Cumberland Bay, South Georgia. 2·8 miles S 24° W of Jason Light. 251 m. (Plate XIX, inset.)

TERRIGENOUS MUD. Similar to sample from St. 29 in general constitution, but perhaps more of the coarser particles. Some small frustules of *Coscinodiscus* from 0·01 to 0·05 mm. in diameter are noted.

Station **31**. 17. iii. 26. 13·5 miles N 89° E of Jason Light, South Georgia. 220 m. (Plate XIX, inset.)

DIATOMACEOUS MUD. The bulk of the sample consists of diatomaceous remains, mostly comminuted, but containing some frustules of *Coscinodiscus*, *Fragilaria* and *Thalassiothrix*. The centric forms are often fairly large, but much of the comminuted material is below 0·01 mm. in diameter. Sponge spicules and green filamentous algae are also present. Many quartz grains reach a diameter of 0·1 mm.; green hornblende (0·05 mm.) is also noted. The greenish tinge of the sediment, and the acquisition of a green colour by the preserving liquid is probably caused by the presence of vegetable pigments.

Station **41**. 28. iii. 26. 16½ miles N 39° E of Banff Point, South Georgia. 272 m. (Plate XIX, inset.)
DIATOMACEOUS MUD. A slightly greenish mud, the bulk of which consists of diatom frustules, mostly fragmentary but with some entire frustules of *Coscinodiscus*, *Fragilaria* and other forms; the centric forms are often especially well-developed. Some grains of quartz and green hornblende are noted. A quantity of greenish flocculent material is present.

Station **42**. 1. iv. 26. Off mouth of Cumberland Bay, South Georgia. From 6·3 miles N 89° E to 4 miles N 39° E of Jason Light. 204 m. (Plate XIX, inset.)
DIATOMACEOUS MUD. This sample consists mostly of finely comminuted diatomaceous material. Some of the centric forms are large, but the majority are below 0·01 mm. in diameter. The navicular and elongate diatoms are small. Sponge spicules are present. The quartz grains, 0·1–0·05 mm. in diameter, are mainly angular in form.

Station **48**. 3. v. 26. 8·3 miles N 53° E of William Point Beacon, Port William, Falkland Islands. Two samples from 105 m. (shoot) and 115 m. (haul). (Plate XVIII.)
SHELLY SAND. Both samples are similar in constitution. They are speckled grey and white sands, consisting mainly of clean white quartz in subangular to rounded grains, with occasional rounded crystals of hypersthene, red garnet, and brown tourmaline. The organic remains include many Foraminifera (*Polystomella* and other rotalids) up to 1 mm. in diameter, echinid spines (mostly broken and some rolled), a few young gastropods and a quantity of broken molluscan shells.

Station **51**. 4. v. 26. Off Eddystone Rock, East Falkland Island. 7 miles N 50° E, to 7·6 miles N 63° E of Eddystone Rock. 115 m. (Plate XVIII.)
FINE SAND. The bulk of the sand grains are less than 0·5 mm. in diameter but some grains are larger; they are mainly subangular fragments of quartz, with occasional rounded grains of hypersthene. There are numerous shells and small pebbles, while among the finer constituents are Foraminifera, echinid spines and shell fragments.

Station **63**. 22. v. 26. Lat. 48° 50′ S. Long. 53° 56′ W. Depth not recorded. (Plate XVII.)
DIATOMACEOUS MUD. The coarser fraction of this greenish mud consists of sand grains up to about 0·1 mm. in diameter; they are subangular to rounded in shape. The finer material also contains some mineral grains (perhaps more angular than the coarser grains), but diatomaceous debris forms the greater bulk. Diatoms are present in variety and include the genera *Coscinodiscus*, *Thalassiosira*, *Cocconeis*, *Fragilaria*, *Thalassiothrix* and *Rhizosolenia*. A considerable proportion of the mud consists of flocculent aggregates formed of disintegrated diatom frustules and their cell contents.

Station **64**. 22. v. 26. Lat. 48° 34′ S. Long. 53° 34′ 30″ W. 4136 m. (Plate XVII.)
GLOBIGERINA OOZE. The very small sample of sandy deposit contains entire examples of *Globigerina* and rotalines, but also much comminuted material. Many glauconite grains occur, some dark green but the majority show a yellowish green colour. Mineral grains, mostly rounded quartz fragments, reach a maximum diameter of 0·5 mm. This is obviously not a typical *Globigerina* ooze, but a mixed deposit which occurs at the margin of the *Globigerina* belt.

Station **71**. 30. v. 26. Lat. 43° 20′ S. Long. 46° 02′ W. 5460 m. (Plate XVII.)
RADIOLARIAN OOZE. A brown unctuous mud. A large part of the material consists of extremely small particles, which form a flocculent "matrix". Quartz grains are dispersed through the deposit, and some reach a diameter of 0·1 mm. The coarse residue after washing shows plentiful Radiolaria. Centric and navicular diatoms are also present. The sample is similar to the deposits from Sts. 74 and 77 which are discussed in greater detail.

Station **74**. 3. vi. 26. Lat. 40° 31′ 40″ S. Long. 38° 14′ 50″ W. 5446 m. (Plate XVII.) Three samples: upper 3 cm., middle 3 cm., and bottom 3 cm., from a core 24 cm. in length.

RADIOLARIAN OOZE. An unctuous brown mud, mainly composed of extremely small particles which together form a flocculent mass. This contains some centric and navicular diatoms, sponge spicules and, more abundantly, Radiolaria. Tests of the latter group are plentiful in coarser washings from the top section of the sample. They are mainly spheroid and discoid forms, such as *Cenosphaera*, *Hexastylus*, *Carposphaera*, *Heliodiscus*, *Porodiscus*, and *Rhopalastrum*. Nasselarian forms are rare and small in size. Radiolaria are not abundant in the meagre washings yielded by the middle and lower sections of the sample.

Mineral grains are common in the upper section, with diameters up to about 0·1 mm. They are mainly angular grains of quartz, but some coloured minerals occur also. On the whole, mineral grains appear to decrease in quantity downwards in the core.

Station **77**. 6. vi. 26. Lat. 39° 19′ 30″ S. Long. 35° 27′ 40″ W. 5186 m. (Plate XVII.)

RADIOLARIAN OOZE. The sample consists of a core 47 cm. long. In general constitution the sample is a brown mud which becomes pale on drying. A considerable part of the deposit is composed of flocculent material; this consists of extremely small particles most of which appear to be isotropic in polarized light, though others are certainly anisotropic. Mingled with this material are mineral grains, Radiolaria and a few other organic remains (such as diatoms), which vary proportionately in different parts of the core.

The top part of the core is extremely rich in Radiolaria, which show a great variety of form. Speaking generally, the spumellarian forms are abundant, but nasselarians are comparatively rare in the residue examined. Of the spumellarians, the spheroid genera *Cenosphaera*, *Carposphaera*, and *Hexastylus*, and the discoid genera *Heliodiscus* and *Porodiscus* are specially abundant and well developed, while *Rhopalastrum* and *Hymeniastrum* are both rare and smaller. Among the few nasselarians, the genera *Sethopyramis*, *Lychnocanium* and *Clathrocyclas* are noted. Only a few small angular mineral grains appear in the residue.

The middle section yields a much smaller residue consisting mainly of Radiolaria. The spheroid and discoid genera are predominant, and similar to those mentioned above; likewise, nasselarian forms are rare.

The lower section contains a larger proportion of mineral grains, which vary in diameter up to 0·1 mm., but some are even larger. Radiolaria are present, especially spheroid and discoid forms, but they are less plentiful than in the higher sections of the core.

Station **78**. 12. vi. 26. Lat. 35° 18′ S. Long. 19° 01′ 10″ W. 3410 m. (Plate XVII.)

GLOBIGERINA OOZE consisting mainly of extremely fine particles, many of which react to polarized light; among these, coccoliths and rhabdoliths are plentiful. Large tests (up to 0·5 mm.) of *Globigerina* occur, but no mineral grains were seen.

Station **83**. 21. vi. 26. Lat. 32° 31′ 50″ S. Long. 1° 23′ 30″ W. 4308 m. (Plate XVII.)

GLOBIGERINA OOZE. A pale ooze formed mainly of comminuted *Globigerina* tests, but some whole shells reach 0·5 mm. in diameter. Some broken echinid spines occur, but no mineral grains are noted. Coccoliths and rhabdoliths occur plentifully in the finer fraction.

Station **84**. 22. vi. 26. Lat. 32° 52′ S. Long. 1° 55′ E. 2233 m. (Plate XVII.)

GLOBIGERINA OOZE. Large tests of *Globigerina* with much comminuted material, coccoliths and rhabdoliths in the finer fraction. No mineral grains were seen.

Station **89**. 28. vi. 26. Lat. 34° 05′ 15″ S. Long. 16° 00′ 45″ E. 3926 m. (Plate XVII, inset.)

GLOBIGERINA OOZE. The sample consists of a core, 30 cm. long. The deposit is closely similar to the samples from Sts. 83 and 84, but there is a slight proportion of small mineral grains (up to 0·05 mm. diameter). Otherwise, there are the usual *Globigerina* tests up to 0·2 mm. across and a considerable proportion of fine material in which coccoliths, rhabdoliths, sponge spicules and foraminiferal fragments can be recognized. No appreciable differences can be detected in slides made from various parts of the core.

Station **93**. 23. ix. 26. Lat. 33° 08′ S. Long. 17° 50′ E. 165 m. (Plate XVII, inset.)

GLAUCONITIC MUD. The sample is largely composed of indefinite flocculent material which encloses particles of foraminiferal shells, coccoliths and fragments of sponge spicules. Held in this flocculent mass are various Foraminifera (including *Globigerina* with a diameter up to 0·3 mm.) and mineral grains. The latter are chiefly colourless angular quartz fragments reaching a diameter of 0·2 mm., but occasional grains of greenish material appear to be glauconite.

Station **94**. 23. ix. 26. Lat. 33° 18′ S. Long. 17° 40′ E. 281 m. (Plate XVII, inset.)

GLAUCONITIC MUD. This sample is mainly composed of rounded and subangular mineral grains averaging about 0·05 mm. in diameter. The grains are chiefly quartz, but some coloured minerals are present. Deep green glauconite occurs in rounded grains. The organic material consists mainly of echinid spines and sponge spicules. The only Foraminifera appear to be a few small (dwarf or immature) specimens of *Globigerina*. There is little flocculent material.

Station **95**. 23–24. ix. 26. Lat. 33° 31′ S. Long. 17° 29′ E. 440 m. (Plate XVII, inset.)

GLAUCONITIC MUD. The sample is much paler in colour than the two preceding (Sts. 93 and 94). It consists mainly of foraminiferal tests (up to 0·2 mm. diameter), most of which are broken and apparently abraded. Sponge spicules also occur. Mineral grains include subangular fragments of quartz (0·1 mm.) and deep green glauconite (0·5 mm.). There is some quantity of finely divided flocculent material in which coccoliths are plentiful.

This is hardly a typical glauconitic mud, as the foraminiferal tests occur in larger proportion than usual, but they have the appearance of drifted material.

Station **96**. 24. ix. 26. Lat. 33° 06′ S. Long. 17° 01′ E. 620 m. (Plate XVII, inset.)

GLAUCONITIC MUD. In the official Station List this sample is described as muddy *Globigerina* ooze. It is essentially a *Globigerina* ooze in which many of the tests are infilled with deep green glauconite. Some grains are seen *in situ*, others are rounded and compound, clearly internal moulds of *Globigerina* shells. The finer fraction includes coccoliths among comminuted shells. The deposit is here classified on the occurrence of glauconite.

Station **97**. 24. ix. 26. Lat. 33° 11′ S. Long. 16° 55′ 30″ E. 995 m. (Plate XVII, inset.)

GLAUCONITIC MUD. A pale deposit consisting largely of *Globigerina* and other Foraminifera; the tests are often broken. The finely divided material contains numbers of tiny calcite rods which seem to be derived by comminution from foraminiferal tests. Sponge spicules and coccoliths also occur. The sample is described as *Globigerina* ooze in the Station List, but the quantity of mineral grains is greater than one would expect in an ooze. Angular grains of quartz reach a diameter of 0·1 mm., and some glauconite grains have a similar size.

In common with samples from Sts. 95 and 96, this deposit is typical neither of glauconitic mud nor of *Globigerina* ooze. Reference to the map shows that the three stations lie on the border-line between the great region of oceanic *Globigerina* ooze to the west, and the area of terrigenous deposits on the landward side. The mixed character of the sediments is thus explained.

Station **98**. 25. ix. 26. Lat. 33° 23′ S. Long. 15° 50′ E. 3640 m. (Plate XVII, inset.)

GLOBIGERINA OOZE. A white, extremely fine-grained ooze, consisting almost entirely of fragmentary foraminiferal tests with some quantity of small unbroken shells of *Globigerina* and other genera. Among the finest comminuted material, coccoliths and rhabdoliths are abundant.

Station **101**. 14. x. 26. Lat. 33° 50′ to 34° 13′ S. Long. 16° 04′ to 15° 49′ E. 3734 m. (Plate XVII, inset.)

GLOBIGERINA OOZE. A small sample consisting of large tests of *Globigerina* (up to 0·3 mm. diameter) with comminuted material, some of which is exceedingly fine grained. There are a few fragmentary sponge spicules and occasional mineral grains, while coccoliths and rhabdoliths occur in the finer material.

Station **102**. 28. x. 26. Lat. 35° 29′ 20″ S. Long. 18° 33′ 40″ E. 1800 m. (Plate XVII, inset.)

GLOBIGERINA OOZE. A grey mud, rather pale when dry. The deposit consists mainly of minute particles (including coccoliths) which form flocculent patches on the glass slip. Foraminiferal shells are fairly abundant, mostly those of *Globigerina*. Sponge spicules also occur. There is a fair proportion of mineral grains, mostly rounded or subangular, up to 0·1 mm. in diameter. While most of the mineral grains are colourless, some rounded green grains, which show aggregate polarization, may be glauconite. Though classified as a *Globigerina* ooze, this deposit is not typical of that group; the proportion of mineral grains is too high and that of Foraminifera is correspondingly small. The station is situated on the margin of a region marked by the occurrence of glauconitic deposits.

Station **117**. 17. xi. 26. Lat. 52° 20′ 40″ S. Long. 3° 48′ 45″ E. 1723 m. (Plate XVII.)

DIATOMACEOUS MUD. A small sample, brownish grey when wet, from "about 5 miles N 72° E of Bouvet Island". The deposit consists mainly of diatom tests, among which *Coscinodiscus*, *Fragilaria* and *Thalassiothrix* are most abundant, the first named attaining a diameter of 0·25 mm. There is a fair quantity of mineral grains, chiefly angular and rounded quartz grains up to 0·2 mm. in diameter; prismatic fragments of green hornblende, up to 0·25 mm. in length, are also present. The proportion of mineral material determines the classification of this deposit as diatomaceous mud rather than diatom ooze.

Station **123**. 15. xii. 26. Off mouth of Cumberland Bay, South Georgia. From 4·1 miles N 54° E of Larsen Point to 1·2 miles S 62° W of Merton Rock. 250 m. (Plate XIX, inset.)

DIATOMACEOUS MUD. An extremely fine-grained mud, with entire tests of centric and navicular diatoms, the diameter of which is mainly below 0·1 mm. The fine material seems to consist in great part of comminuted diatoms. Quartz grains are present in fair quantity, but are mainly less than 0·05 mm. in diameter; the occasional grains of green hornblende are also small.

Station **129**. 19. xii. 26. Lat. 53° 28′ 30″ S. Long. 37° 08′ W. 1001 m. (Plate XIX.)

DIATOMACEOUS MUD. A very small sample which has settled out into black and light-coloured layers, representing the approximate separation of detrital and organic constituents. The organic material contains centric and navicular diatoms, the former reaching a diameter of 0·2 mm. Elongate diatoms and sponge spicules are present in some abundance and occasional Radiolaria are noted. Much light flocculent material consists entirely of fragmentary diatom tests. Mineral grains, reaching a diameter of 0·1 mm., are present in fair quantity. They are mostly rounded and subangular fragments of quartz, but blue-green prismatic grains of hornblende and some opaque grains occur. No stones are present in the sample, though these are recorded in the Station List.

Station **131**. 20. xii. 26. Lat. 53° 59′ 30″ S. Long. 36° 11′ W. 240 m. (Plate XIX, inset.)

DIATOMACEOUS MUD. The material consists largely of diatoms in some variety, among which *Fragilaria* and *Coscinodiscus* are predominant, the latter reaching 0·2 mm. in diameter. Sponge spicules are also present. There is some quantity of mineral grains which rarely attain 0·1 mm. in diameter; they are mainly rounded colourless quartz fragments, but prismatic green hornblende is noted. Stones are recorded in the Station List but there are none in the sample.

Station **136**. 21. xii. 26. Lat. 54° 22′ S. Long. 35° 21′ W. 246 m. (Plate XIX.)

GLAUCONITIC MUD. The sample is a light grey mud when dry, but is greenish when wet. No stones are present. The bulk of the material consists of mineral grains reaching a diameter of 0·2 mm., though the average size is much less. There is probably a fair variety of minerals, among which green hornblende is conspicuous, but the large majority of grains are subangular fragments of quartz. Deep green glauconite is present, sometimes filling the canals of sponge spicules. The finer material includes diatom frustules, mainly fragmentary, but whole tests of *Coscinodiscus* and *Fragilaria* are present. The apparent absence of calcareous tests is noteworthy, in view of their constant association with glauconite elsewhere.

Station **145**. 7. i. 27. Stromness Harbour, South Georgia; between Grass Island and Tonsberg Point. 26–35 m. (Plate XIX, inset.)

DIATOMACEOUS MUD. The coarser constituents include a variety of diatoms, chiefly *Coscinodiscus* (up to 0·2 mm. in diameter), *Fragilaria*, *Cocconeis* and *Licmophora* with occasional examples of *Pleurosigma*. Simple and branched sponge spicules, amphipod fragments and sea-weeds were also noted. Mineral grains, mainly quartz fragments, reach 0·2 mm. in diameter, but the average size is much smaller. The finest material consists of mineral particles together with comminuted diatoms, and other organic debris.

Station **151**. 16. i. 27. Lat. 53° 25′ S. Long. 35° 15′ W. 3200 m. (Plate XIX.)

DIATOMACEOUS MUD. The organic constituent is almost entirely diatomaceous, frustules of *Coscinodiscus*, *Fragilaria* and *Thalassiothrix* being abundantly represented. Occasionally Radiolaria and sponge spicules are seen. Mineral grains up to 0·2 mm. in diameter occur in some quantity; the size of the grains is larger than would be expected at this depth and locality.

Station **157**. 20. i. 27. Lat. 53° 51′ S. Long. 36° 11′ 15″ W. 970 m. (Plate XIX, inset.)

DIATOMACEOUS MUD. Stones are reported for this deposit in the Station List but none is present in the small sample. The organic constituents consist of the usual diatomaceous assemblage (*Coscinodiscus*, *Fragilaria* and *Thalassiothrix*) together with sponge spicules. The numerous mineral grains are rounded and subangular in shape, and reach 0·2 mm. in diameter.

Station **160**. 7. ii. 27. Lat. 53° 43′ 40″ S. Long. 40° 57′ W, near Shag Rocks. 177 m. (Plate XVII.)

SAND. This is a very "mixed" deposit, described in the official Station List as "Grey mud with stones and rock". One stone, 8 mm. in diameter, is present in the small sample available. The deposit consists of mineral grains and rock fragments up to 1 mm. in diameter, *Globigerina* and other Foraminifera, together with exceedingly fine-grained, supernatant material which includes the diatoms, *Coscinodiscus*, *Thalassiosira*, *Fragilaria*, *Rhizosolenia*.

Station **162**. 17. ii. 27. Lat. 60° 48′ S. Long. 46° 08′ W. 320 m. (Plate XVII.)

DIATOMACEOUS MUD. A sample obtained off Signy Island, South Orkneys, and described as "green mud" in the official Station List. The sediment is composed largely of fine-grained material which appears to be comminuted diatoms, and there are many whole frustules of *Coscinodiscus*, *Fragilaria* and *Rhizosolenia*. Mineral grains are generally less than 0·05 mm. in diameter and most of them are angular fragments of quartz, but prismatic grains of green hornblende and flakes of white mica also occur.

Station **167**. 20. ii. 27. Lat. 60° 50′ 30″ S. Long. 46° 15′ W. 244–344 m. (Plate XVII.)

DIATOMACEOUS MUD. A fine-grained sediment consisting largely of mineral grains, only a few of which attain a diameter of 0·2 mm. Quartz, hornblende and white mica are noted. Some sponge spicules are present, and also frustules of *Coscinodiscus* and *Fragilaria*. The finer fraction of the sediment appears to consist of comminuted diatom frustules.

Station **169**. 22. ii. 27. Lat. 60° 48′ 50″ S. Long. 51° 00′ 20″ W. 2514 m. (Plate XVII.)

DIATOMACEOUS MUD. The sample consists of two sections of core, in all about 40 cm. long. Various parts of the core have been examined microscopically, but no appreciable differences have been detected throughout its length. This dark, greenish grey mud consists essentially of diatom frustules in considerable variety. Centric forms, especially *Coscinodiscus* and *Thalassiosira*, are conspicuous by their size and abundance, while *Biddulphia* is less numerous; navicular genera are represented by *Fragilaria* and *Achnanthes*; and among elongate forms, *Rhizosolenia* is both abundant and well-developed, while *Corethron* is smaller and less plentiful. There is a quantity of comminuted frustules, the particles of which adhere and form flocculent groups. Mineral grains are present in fair quantity, and reach a diameter of about 0·1 mm. They include grains of quartz and green hornblende and flakes of white mica. The deposit might almost be called a diatom ooze, but the proportion of mineral grains, though not great, is a real distinction between this sample and that from St. 12, for instance.

Station **171**. 25. ii. 27. Lat. 62° 07′ S. Long. 57° 03′ W. 16 miles off Cape Melville, King George Island, South Shetlands. 1542 m. (Plate XX.)

DIATOMACEOUS MUD. This brownish grey mud contains abundant mineral grains, many exceedingly small and the great majority less than 0·1 mm. in diameter. Besides the quartz grains, prismatic fragments of green hornblende and splinters of brown volcanic glass are noted. There is a large proportion of indeterminate flocculent material which contains small diatoms (whole and fragmentary frustules of *Coscinodiscus*, *Fragilaria* and *Rhizosolenia*) together with sponge spicules.

Station **172**. 26. ii. 27. Lat. 62° 59′ S. Long. 60° 28′ W. Off Deception Island, South Shetlands. 525 m. (Plate XX.)

GRAVEL. The sample consists of black pebbles, presumably of volcanic rock, on some of which are adherent polyzoa.

Station **175**. 2. iii. 27. Lat. 63° 17′ 20″ S. Long. 59° 48′ 15″ W. Bransfield Strait, South Shetlands. 200 m. (Plate XX.)

SAND. The sample consists of a small quantity of sand. The particles are mainly coarse, the larger grains reaching a diameter of 0·5 mm., but some of the material is finer and shows a variety of minerals. Quartz is most abundant, while hornblende and volcanic glass are noted among the coloured grains. No organic remains were seen.

Station **180**. 11. iii. 27. 1·7 miles west of northern point of Gand Island, Palmer Archipelago. 160 m. (Plate XX.)

TERRIGENOUS MUD. This pale grey mud consists almost entirely of detrital mineral grains, chiefly quartz, but green hornblende (up to 0·2 mm. diameter) and occasional splinters of volcanic glass are conspicuous. Only occasional diatoms and sponge spicules are seen.

Station **185**. 16. iii. 27. Gerlache Strait, Palmer Archipelago. 3·5 miles S 119° E of Cape van Wycks, Anvers Island. 598 m. (Plate XX.)

DIATOMACEOUS MUD. Roughly half the bulk of this brownish grey mud consists of fairly angular detrital grains which reach a diameter of 0·1 mm. Occasionally frustules of *Coscinodiscus* are larger than this. The other half consists of flocculent material which includes tiny mineral grains, small diatoms (*Fragilaria*, etc.), fragments of sponge spicules and indeterminate debris.

Station **187**. 18. iii. 27. Lat. 64° 48′ 30″ S. Long. 63° 31′ 30″ W. Neumayr Channel, Palmer Archipelago. Two samples from depths of 200 and 259 m. respectively. (Plate XX.)

DIATOMACEOUS MUD. The sample from 200 m. is a brownish mud consisting of flocculent material with some mineral grains whose diameter is usually less than 0·05 mm. Occasional navicular diatoms and sponge spicules are present.

The sample from 259 m. is a grey mud, largely of detrital origin, with mineral grains reaching more than 0·2 mm. in diameter and consisting chiefly of quartz and green hornblende, together with fragments of volcanic glass. Centric diatoms (about 0·05 mm. diameter), occasional Foraminifera and sponge spicules are noted.

Station **191**. 25. iii. 27. Gerlache Strait, Palmer Archipelago. 2·5 miles N 114° E of Cape Astrup, Wiencke Island. 310 m. (Plate XX.)

DIATOMACEOUS MUD. A light grey mud with abundant detrital minerals, some of which are 0·2 mm. in diameter, including grains of green hornblende, some of which are idiomorphic. These are enclosed in flocculent material, apparently organic debris, which also contains small diatoms, both centric and navicular forms, but these are not abundant.

Station **192**. 27. iii. 27. Lat. 64° 14′ S. Long. 61° 49′ W. Off Cape Kaiser, Brabant Island, Palmer Archipelago. 800 m. (Plate XX.)

DIATOMACEOUS MUD. This brownish grey mud is mainly a mass of flocculent material, apparently organic debris, which encloses small centric and navicular diatoms (0·02 mm.) together with comminuted frustules. Some of the material may be mineral grains, but determination of these tiny fragments is difficult. Occasionally larger grains (0·1 mm. diameter) of quartz and volcanic glass are seen.

Station **194**. 28. iii. 27. Lat. 62° 57′ 30″ S. Long. 60° 22′ W., 2½ miles east of Deception Island, South Shetlands. 812 m. (Plate XX.)

DIATOMACEOUS MUD. A brownish grey mud containing numerous mineral grains, some of which reach a diameter of 0·5 mm., though the average size is much less. The largest are fragments of brown volcanic glass (0·5 mm.), but angular and subangular grains of quartz and green hornblende are also noted. Organic remains are not conspicuous, though frustules of *Coscinodiscus* and *Fragilaria*, together with sponge spicules, do occur. The amount of flocculent material is subordinate.

Station **195**. 30. iii. 27. Lat. 62° 07′ S. Long. 58° 28′ 30″ W. Admiralty Bay, King George Island, South Shetlands. 391 m. (Plate XX.)

SAND. This sample is a non-graded sand, of which the largest grains have a diameter of about 0·25 mm.; they are chiefly rounded and subangular grains of quartz, felspar and green hornblende. The only muddy material has formed a coherent film on the surface in the jar; it shows the same abundance of detrital minerals in smaller fragments. Organic remains are scarce and comprise a few sponge spicules and some small diatom frustules (*Coscinodiscus* and *Fragilaria*).

Station **196**. 3. iv. 27. Lat. 62° 17′ 30″ S. Long. 58° 21′ W. Bransfield Strait, South Shetlands. Two samples from depths of 720 and 1011 m. respectively. (Plate XX.)

TERRIGENOUS MUD. Both samples are brownish grey muds, consisting of homogeneous flocculent material in which small mineral grains are embedded. Occasionally, larger grains (0·2 mm.) of quartz and green hornblende are seen. A few diatoms (*Coscinodiscus*, *Fragilaria* and *Rhizosolenia*) and sponge spicules are the only organic forms recognized.

Station **197**. 3. iv. 27. Lat. 62° 27′ S. Long. 58° 11′ 30″ W. Bransfield Strait, South Shetlands. 1974 m. (Plate XX.)

DIATOMACEOUS MUD. A brownish grey mud of homogeneous constitution. It consists mainly of flocculent organic debris, some flocks having a greenish tinge. Diatom fragments form the bulk of the material, together with unbroken frustules of *Thalassiosira*, *Coscinodiscus*, *Fragilaria*, *Rhizosolenia* and *Corethron*. Some of these diatoms retain their protoplasmic content. One textularian Foraminifer is noted together with the usual sponge spicules. Mineral grains, quartz and green hornblende, occur in small quantity; they are mostly less than 0·05 mm. in diameter, and few reach 0·1 mm.

Station **198**. 3–4. iv. 27. Lat. 62° 38′ S. Long. 58° 04′ W. Bransfield Strait, South Shetlands. 1600 m. (Plate XX.)

DIATOMACEOUS MUD. A brownish grey mud similar to that from St. 197. It shows the same characters under the microscope, but no Foraminifera were seen.

Station **199**. 4. iv. 27. Lat. 62° 49′ S. Long. 57° 56′ 30″ W. Bransfield Strait, South Shetlands. 735 m. (Plate XX.)

DIATOMACEOUS MUD. This sample of brownish mud contains one pebble roughly 1 cm. in diameter; it is more sandy than the preceding sample and does not coagulate on drying. The average size of the abundant quartz grains is larger than in samples at Sts. 197 and 198, the maximum diameter being about 0·2 mm. Green hornblende occurs also. Centric diatoms, *Coscinodiscus* and *Thalassiosira*, are plentiful and reach 0·1 mm. across; the smaller forms include *Cocconeis*, *Fragilaria*. Sponge spicules are noted. Flocculent material of the usual character forms a "matrix", in which the diatoms and mineral grains are enclosed.

Station **200**. 4. iv. 27. Lat. 69° 59′ 30″ S. Long. 57° 49′ W. Bransfield Strait, South Shetlands. 345 m. (Plate XX.)

DIATOMACEOUS MUD. A very small sample of brownish mud, which differs from the preceding in size of the mineral grains and the slight degree of rounding. Quartz grains reach a diameter of

0·25 mm., and the average size is estimated at about 0·05 mm. Centric diatoms, *Coscinodiscus* and *Thalassiosira*, reach 0·1 mm. in diameter, while *Cocconeis* and *Fragilaria* are also well developed. These forms occur with sponge spicules in the flocculent material which, however, appears to be less in proportionate bulk than in the preceding samples (Sts. 197, 198 and 199).

Station **201**. 5. iv. 27. Lat. 63° 00′ 30″ S. Long. 59° 06′ 30″ W. Bransfield Strait, South Shetlands. 343 m. (Plate XX.)

DIATOMACEOUS MUD. This small sample contains numerous grains of quartz and green hornblende, the average diameter of which is probably between 0·1 and 0·05 mm. Angular fragments of vesicular volcanic glass are also conspicuous. The grains are held in flocculent material composed of diatom tests (whole and fragmentary) and organic debris, of which some at least consists of the protoplasmic constituent of the diatoms.

Station **202**. 5. iv. 27. Lat. 62° 48′ S. Long. 60° 05′ W. Bransfield Strait, South Shetlands. 909 m. (Plate XX.)

DIATOMACEOUS MUD. A considerable proportion of this dark grey mud consists of detrital grains, angular to rounded in shape; some of the grains are more than 0·1 mm. in diameter, but also there are many more whose diameter is less than 0·02 mm. Fragments of volcanic glass are sharply angular while quartz grains are usually more rounded. Flocculent material is composed largely of tiny mineral grains or rods, with some fragmentary diatom frustules. The genera *Coscinodiscus*, *Thalassiosira*, *Cocconeis*, *Fragilaria* and *Rhizosolenia* are present but not abundant.

Station **203**. 5–6. iv. 27. Lat. 62° 56′ S. Long. 59° 50′ W. Bransfield Strait, South Shetlands. 949 m. (Plate XX.)

DIATOMACEOUS MUD. A brownish mud with a conspicuous proportion of detrital grains, some of which reach a diameter of 0·25 mm. Green hornblende and brown volcanic glass are noted in addition to the predominant quartz. The fine-grained fraction, of the usual flocculent character, includes tiny mineral fragments, sponge spicules, comminuted diatom frustules, and small diatoms about 0·05 mm. in diameter. The genera *Thalassiosira*, *Coscinodiscus*, *Cocconeis* and *Fragilaria* are represented.

Station **204**. 6. iv. 27. Lat. 63° 05′ S. Long. 59° 42′ W. Bransfield Strait, South Shetlands. 943 m. (Plate XX.)

DIATOMACEOUS MUD. Similar in general character to the sample from St. 203. Some of this sediment was spread on a glass slip in a thick film of water; movement of the cover-glass caused groups of sand grains to be rafted along on pieces of flocculent material which preserved their continuity.

Station **206**. 6. iv. 27. Lat. 63° 26′ S. Long. 59° 28′ W. Bransfield Strait, South Shetlands. 310 m. (Plate XX.)

DIATOMACEOUS MUD. This is essentially similar to the sample from St. 204, consisting mainly of flocculent material which encloses diatom frustules and mineral grains. The latter are usually very small, but there are larger grains (up to 0·1 mm. diameter) of quartz, volcanic glass and green hornblende. The diatoms include representatives of the genera *Coscinodiscus*, *Thalassiosira*, *Cocconeis*, *Fragilaria*.

Station **209**. 14. iv. 27. Port Foster, Deception Island, South Shetlands. 168 m. (Plate XX.)

TERRIGENOUS MUD. The mineral fraction consists mainly of angular fragments of brown, vesicular, volcanic glass which vary in size between a diameter of about 0·2 mm. and exceedingly small dimensions. Some flocculent matter is present, with the diatoms *Thalassiosira*, *Cocconeis*, *Licmophora* and *Fragilaria*, but unbroken frustules are not abundant. The flocculent material causes agglutination so that the deposit forms a coherent mass on drying.

Station **211**. 15. iv. 27. Lat. 62° 35′ S. Long. 63° 20′ W. 2865 m. (Plate XX.)

DIATOMACEOUS MUD. A brown-grey mud containing abundant mineral grains which are usually less than 0·05 mm. in diameter. The grains are mainly of quartz, but occasional fragments of green hornblende and glaucophane occur. The bulk of the deposit consists of flocculent material which surrounds the sand grains and diatoms. Among the latter are species of *Fragilaria*, *Rhizosolenia*, *Thalassiosira* and *Coscinodiscus*. Some of the diatoms retain their protoplasmic contents, and much of the flocculent matter is doubtless of organic origin.

Station **212**. 16. iv. 27. Lat. 61° 15′ S. Long. 64° 42′ 50″ W. 3350 m. (Plate XVII.)
DIATOMACEOUS MUD. A brown mud, essentially similar to that from St. 211, but the mineral grains attain a larger size, about 0·1 mm. in diameter. The occurrence of quartz, green hornblende and white mica is noted. The organic material is chiefly diatomaceous but some arthropod remains and eroded tests of *Globigerina* occur.

Station **228**. 2. v. 27. Lat. 53° 33′ S. Long. 61° 49′ 30″ W. 660 m. (Plate XVIII.)
DIATOMACEOUS MUD. A grey mud with abundant detrital grains up to 0·1 mm. diameter. Quartz grains preponderate but occasional grains of hypersthene are seen. Large (up to 0·1 mm.) centric diatoms (e.g. *Coscinodiscus*), navicular forms (especially *Fragilaria*) and sponge spicules are present. Flocculent material is conspicuous, but not in such large proportion as in the foregoing samples.

Station **230**. 5. v. 27. Lat. 53° 17′ S. Long. 60° 25′ W. 675 m. (Plate XVIII.)
TERRIGENOUS MUD. This grey mud has an abundance of very small mineral grains (quartz and occasionally hypersthene) in a matrix of flocculent material which is more granular in appearance than usual. Recognizable organic remains are virtually absent.

Station **235**. 29. v. 27. Lat. 50° 45′ S. Long. 56° 18′ 30″ W. 600 m. (Plate XVII.)
SAND. A fine-grained sand or silt, some of the constituent grains (chiefly quartz) reaching a diameter of 0·25 mm. Fragments of green hornblende are smaller and less numerous. A few Foraminifera and diatoms occur, but organic remains other than sponge spicules are scarce. The preservative liquid has acquired a slight greenish tinge.

Station **236**. 29–30. v. 27. Lat. 50° 35′ 30″ S. Long. 55° 59′ 15″ W. 612 m. (Plate XVII.)

Station **237**. 30. v. 27. Lat. 50° 17′ 40″ S. Long. 55° 31′ 30″ W. 904 m. (Plate XVII.)
SAND. The samples from Sts. 236 and 237 are so similar that they may be described together. The sand grains, mostly quartz, reach a diameter of 0·5 mm.; some green hornblende is present. Large opaque grains, which form a dark layer in the sediment, together with smaller yellow-green grains show the characters of glauconite. Flocculent matter is present in small amount. The organic fraction includes some Foraminifera (especially *Globigerina*), centric diatoms and sponge spicules. Some of the latter are infilled with yellow-green "glauconitic" material which shows aggregate polarization between crossed nicols.

Station **263**. 19. vii. 27. Lat. 33° 06′ S. Long. 17° 08′ W. 461 m. (Plate XVII, inset.)
GLAUCONITIC MUD. The material has settled into layers during storage. The upper part consists of homogeneous, extremely fine-grained, flocculent material with a few sponge spicules and occasional mineral grains. The lower layer contains abundant *Globigerina* and some rounded grains of glauconite, up to 0·15 mm. diameter. The fine-grained constituent apparently consists of comminuted foraminiferal tests and coccoliths with a considerable proportion of protoplasmic debris, the latter having a greenish tinge. Some of the *Globigerina* shells are infilled with glauconite.

Station **264**. 19–20. vii. 27. Lat. 33° 06′ S. Long. 16° 55′ E. 645 m. (Plate XVII, inset.)
GLAUCONITIC MUD. A "mixed" deposit consisting of muddy flocculent material with a considerable proportion of mineral grains and foraminiferal tests. The mineral fragments (chiefly quartz) reach a diameter of 0·1 mm. Some bright green glauconite grains, rounded to angular in shape, have about the same average size, but one grain measured 0·25 mm. in diameter. The Foraminifera often retain their protoplasmic contents; *Globigerina* and *Frondicularia* were noted as reaching a diameter of 0·2 mm. Coccoliths are frequently seen in the finer material.

Station **265**. 20. vii. 27. Lat. 33° 06′ 30″ S. Long. 16° 32′ E. 1620 m. (Plate XVII, inset.)

GLAUCONITIC MUD. A pale, fine-grained sediment, mainly flocculent material in which are scattered Foraminifera and a few sand grains. The flocculent material seems to be in part comminuted foraminiferal shells together with coccoliths and rhabdoliths, in part decayed organic matter. The minerals are chiefly quartz and glauconite, but both are scarce. The Foraminifera are mainly *Globigerina*.

This and the preceding sample (St. 264) are classified in the official Station List as *Globigerina* ooze. But as Foraminifera by no means form the bulk of the deposit, the sediments are here regarded as glauconitic mud, with a subordinate proportion of foraminiferal debris.

Station **283**. 13. viii. 27. Off Annobon, Gulf of Guinea. 0·75 to 1 mile N 12° E of Pyramid Rock, Annobon. 18–30 m.

SHELL SAND. The sand consists of foraminiferal and small molluscan shells which average about 1 mm. in diameter. Some of the Foraminifera (e.g. *Cristellaria*) are larger than this, but the shells of *Globigerina* are smaller; large textularians are also conspicuous. Few mineral grains occur.

Station **363**. 26. ii. 30. 2·5 miles S 80° E of south-east point of Zavodovski Island, South Sandwich Islands. 329 m. (Plate XVII.)

FINE SAND. The bulk of the sample is a dark brown sand, the grains reaching a diameter of 0·5 mm. and ranging downwards in size, the average being about 0·25 mm. Much of the material consists of brown volcanic glass in sharply angular fragments, and many of the grains are vesicular: the sand owes its dark colour to this material. Quartz grains (also up to 0·5 mm. diameter) appear to be more rounded.

The fine-grained material, which has formed a film on the sand in the storage jar, is a mixture of tiny mineral particles and diatomaceous debris. *Fragilaria* and *Thalassiothrix* appear to be the most abundant genera, while centric forms (*Coscinodiscus* and *Thalassiosira*) are not especially common in occurrence.

Station **366**. 6. iii. 30. 4 cables south of Cook Island, South Sandwich Islands. 340 m. (Plate XVII.)

FINE SAND. A dark brown, nearly black, sand composed almost entirely of fragments of quartz and volcanic glass. In size the grains range from a diameter of about 0·1 mm. to exceedingly small particles. Most of the grains are markedly angular in shape, though some have suffered a slight degree of rounding. A subordinate quantity of flocculent material gives a green colour to the preserving liquid. The presence of sponge spicules and frustules of *Coscinodiscus*, *Cocconeis* and *Fragilaria* is noted. The deposit is similar to that from St. 363, but is rather finer in grain.

Station **425**. 4. ix. 30. Lat. 34° 50′ S to 34° 53¾′ S. Long. 26° 41½′ E to 26° 30½′ E. 4107 m.

GLOBIGERINA OOZE. The sample is perhaps more sandy than usual in a typical ooze. Tests of *Globigerina* and *Orbulina* are abundant and well developed. Diatoms and sponge spicules also occur, but the former are not numerous. Coccoliths are abundant in the finer fraction, while rhabdoliths (as usual) are less in evidence.

Station **1165**. 4. iii. 33. Lat. 40° 54·7′ S. Long. 9° 25·5′ E. 4642 m. (Plate XVII.)

RADIOLARIAN OOZE. This is a brownish mud composed largely of organic debris, with some admixture of sand grains which are generally less than 0·05 mm. in diameter. The coarser fraction consists mainly of radiolarian tests, among which sphaeroid forms are dominant, discoid forms are of common occurrence, while nasselarians are comparatively rare. The genera recognized are *Cenosphaera*, *Carposphaera*, *Xiphosphaera*, *Hexastylus*, *Heliodiscus*, *Porodiscus*, *Hymeniastrum*, *Rhopalastrum* and *Lithostrobus*. Some Foraminifera (*Globigerina*), diatoms (*Coscinodiscus*), and anchor-shaped spines of the holothuroidean *Synapta* are noted.

R.R.S. 'WILLIAM SCORESBY'

Station **WS 18**. 26. xi. 26. Lat. 54° 07′ S. Long. 36° 23′ W. 113 m. (Plate XIX.)

Diatomaceous mud. A small sample containing much detrital mineral material. Large mineral grains, up to 0·1 mm. across, are mingled with exceedingly fine sediment. The latter includes comminuted diatoms and possibly other organic debris. Centric diatoms, some more than 0·1 mm. in diameter, and sponge spicules are present.

Station **WS 20**. 28. xi. 26. Lat. 53° 52′ 30″ S. Long. 36° 00′ W. 535 m.

A small sample in a glass tube which is enclosed with a label in a bottle. The label states—"Brought up in a net lowered to 500 m. and hauled to 250, then closed. Lucas Sounder gave 535 m., rock".

The tube contains a small quantity of sand containing grains up to 0·25 mm. in diameter. There is no muddy material. Some tests of *Globigerina* occur.

As this sample is probably incomplete it is not classified with the others in this report and the station is not entered on Plate XIX.

Station **WS 26**. 18. xii. 26. Lat. 53° 33′ 15″ S. Long. 37° 45′ 15″ W. 1180 m. (Plate XIX.)

Diatomaceous mud. A greenish grey mud; the preservative liquid has acquired a greenish tinge. This sediment might be classed as diatom ooze except for the presence of green flocculent material and the proportion of mineral grains which reach a diameter of 0·1 mm., though the majority are below 0·05 mm. Quartz and green hornblende are the only conspicuous minerals. The sample as a whole is extremely fine grained and the diatoms are small. *Coscinodiscus*, *Rhizosolenia* and *Fragilaria* are the chief genera.

Station **WS 28**. 19. xii. 26. Lat. 53° 48′ 15″ S. Long. 38° 13′ W. Two samples from depth of 346 and 150 m. respectively. (Plate XIX.)

Diatomaceous mud. The sample from 346 m. consists of abundant mineral grains (a few up to 0·4 mm. diameter) enclosed in a "matrix" of flocculent material. The latter consists of diatoms (*Coscinodiscus* and *Fragilaria*), tiny mineral grains and indeterminable debris, some of which appears to be of diatomaceous origin.

A label in the bottle containing the second sample states, "N 70 V touched bottom at 145 m." The sample is a clean sand with many dark and opaque grains which appear to be rock fragments; many grains reach a diameter of 0·25 mm. and more. This is probably an incomplete sample, the finer constituents having been lost.

Station **WS 32**. 21. xii. 26. Mouth of Drygalski Fjord, South Georgia. 225 m. (Plate XIX.)

Diatomaceous mud. A grey sediment of the usual diatomaceous character. *Fragilaria*, *Coscinodiscus* and *Thalassiosira* are the chief diatoms. The sand grains are small, being less than 0·05 mm. in diameter. Green hornblende, as well as quartz, is abundantly represented among the grains.

Station **WS 33**. 21. xii. 26. Lat. 54° 59′ S. Long. 35° 24′ W. 135 m. (Plate XIX.)

Diatomaceous mud. A grey mud containing a fair amount of detrital grains, some reaching 0·2 mm. in diameter, many up to 0·1 mm. Green hornblende is of common occurrence. There is much flocculent material containing diatom frustules (*Coscinodiscus*, *Fragilaria*, etc.) and sponge spicules; the masses of this material often show a green colour which is sufficient to give a greenish tinge to the whole sample when wet.

Station **WS 37**. 22. xii. 26. Lat. 54° 45′ S. Long. 35° 11′ W. 318 m. (Plate XIX.)

Diatomaceous mud. A grey mud similar to that from St. WS 33. There are abundant detrital grains, some 0·2 mm. in diameter, among which quartz, felspar and green hornblende are noted. Diatoms are abundant, whole tests are more conspicuous than in the foregoing sample and perhaps in greater variety; centric forms (*Coscinodiscus* and *Thalassiosira*) reach a diameter of 0·1 mm. The flocculent material contains green masses, some of which firmly enwrap sand grains. It may be suggested that the enclosure of detrital grains in the buoyant flocculent material is an important factor in the transport of the mineral grains far from their original source.

Station **WS 39**. 23. xii. 26. Lat. 54° 08′ S. Long. 35° 43′ W. 237 m. (Plate XIX.)

DIATOMACEOUS MUD. A grey mud which differs from the preceding sample in the somewhat smaller average size of the sand grains, and the greater proportionate bulk of the flocculent constituent, but otherwise very similar. The greenish tinge of the sediment is due to the presence of green flocculent masses.

Station **WS 40**. 7. i. 27. Lat. 55° 09′ S. Long. 35° 58′ W. 183 m. (Plate XIX.)

DIATOMACEOUS MUD.

Station **WS 41**. 7. i. 27. Lat. 54° 32′ 45″ S. Long. 36° 43′ 45″ W. 140 m. (Plate XIX.)

DIATOMACEOUS MUD.

Station **WS 42**. 7. i. 27. Lat. 54° 41′ 45″ S. Long. 36° 47′ W. 175 m. (Plate XIX.)

DIATOMACEOUS MUD.

Station **WS 43**. 7–8. i. 27. Lat. 54° 54′ S. Long. 36° 50′ W. 200 m. (Plate XIX.)

DIATOMACEOUS MUD. These four samples are very similar, and are typical of diatomaceous muds in general. The mineral grains (quartz and green hornblende) are usually small, but some attain diameters up to 0·2 mm. The detrital grains are enclosed in greenish masses of flocculent material which contains small diatoms.

Station **WS 45**. 8. i. 27. Lat. 54° 38′ 30″ S. Long. 37° 30′ 55″ W. 180 m. (Plate XIX.)

DIATOMACEOUS MUD. A grey mud enclosing some hard black pebbles, 1 cm. in diameter. There are abundant detrital grains including green hornblende up to 0·2 mm. in diameter, while a few reach 0·5 mm. across. Centric diatoms are conspicuous, and sponge spicules are frequent in occurrence. The finer material includes diatom debris and indeterminable flocculent matter.

Station **WS 46**. 8. i. 27. Lat. 54° 20′ 15″ S. Long. 37° 32′ 30″ W. 194 m. (Plate XIX.)

DIATOMACEOUS MUD. A grey mud with small black pebbles, essentially like the preceding deposit. A fair proportion of mineral grains is enclosed in fine-grained flocculent material which contains the usual diatoms. Some grains of quartz and green hornblende reach a diameter of 0·1 mm.

Station **WS 47**. 9. i. 27. Lat. 54° 22′ S. Long. 37° 50′ W. 160 m. (Plate XIX.)

DIATOMACEOUS MUD. A grey mud, paler in colour than the preceding sample, but of essentially similar character. Detrital grains, especially quartz and (more rarely) green hornblende, form a considerable bulk in the deposit; they are mostly below 0·05 mm. in diameter, but some reach 0·25 mm. Centric diatoms are conspicuous in the flocculent "matrix".

Station **WS 48**. 9. i. 27. Lat. 54° 24′ S. Long. 38° 09′ W. 224 m. (Plate XIX.)

DIATOMACEOUS MUD. A grey mud when dry, greenish grey when wet. This sediment is almost a diatom ooze with centric (up to 0·2 mm. in diameter), navicular and elongate diatoms, together with some sponge spicules, but there is a considerable quantity of green flocculent matter. There are few mineral grains and those are mostly of small size. A fragment of rock occurs in the sample, measuring 2·5 by 1·3 cm.; in thin section this is seen to be a tuff containing fragments of felspar and green hornblende.

Station **WS 49**. 9. i. 27. Lat. 54° 28′ S. Long. 38° 22′ 15″ W. 223 m. (Plate XIX.)

DIATOMACEOUS MUD. This sample is darker in colour than the preceding, and the preservative liquid has acquired a green tinge. There are abundant detrital grains, mostly less than 0·05 mm. in diameter, but some (including green hornblende) greater than 0·1 mm. These and large centric diatoms are embedded in flocculent material of the usual character.

Station **WS 50**. 9. i. 27. Lat. 54° 30′ 30″ S. Long. 38° 40′ 30″ W. 230 m. (Plate XIX.)

DIATOMACEOUS MUD. The sample has dried to a light grey colour. The pale colour appears to be due to the relative scarcity of dense flocculent masses; the fine material is abundant, but consists almost entirely of comminuted diatom tests and mineral grains. Frustules of *Coscinodiscus* and *Fragilaria* are abundant, *Rhizosolenia* less plentiful and sponge spicules are present in small quantity.

The numerous detrital grains are mostly below 0·05 mm. in diameter, but a few reach 0·1 mm.; they include small crystals of green hornblende.

Station **WS 52**. 10. i. 27. Lat. 54° 03′ 30″ S. Long. 38° 35′ W. 184 m. (Plate XIX.)

Diatomaceous mud. A grey mud with abundant detrital grains mostly below 0·05 mm. in diameter, but some reaching 0·25 mm. The flocculent material encloses frustules of *Coscinodiscus* (large), *Fragilaria*, *Cocconeis* and *Rhizosolenia*, together with sponge spicules and much comminuted material.

Station **WS 63**. 20–21. i. 27. Lat. 54° 36′ S. Long. 39° 14′ W. 1752 m. (Plate XIX.)

Diatomaceous mud. No stones are present in this sample of grey mud, though such material is reported in the Station List. The detrital grains, including green hornblende, attain a diameter of 0·1 mm. The finer fraction consists largely of diatom frustules; the larger centric tests are broken, but the smaller ones (mostly navicular forms) are whole. Occasional Radiolaria and sponge spicules are noted.

Station **WS 71**. 23. ii. 27. Lat. 51° 38′ S. Long. 57° 32′ 30″ W. 6 miles N 60° E of Cape Pembroke Light, East Falkland Island. 80 m. (Plate XVIII.)

Sand. The label states: "Bottom sample taken from contents of trawl". The mineral grains reach a diameter of 0·5 mm., and there is apparently little material of medium grade, though some very small grains are present. There is a considerable proportion of calcareous matter, such as Foraminifera, echinid spines and small molluscan shells. Many of the shells are undamaged but there is also much broken material, some exceedingly small. The Foraminifera include miliolines (*Biloculina* and *Miliolina*) and rotalines (*Globigerina* and *Anomalina*).

Station **WS 76**. 11. iii. 27. Lat. 51° 00′ S. Long. 62° 02′ 30″ W. 207 m. (Plate XVIII.)

Fine dark sand. A fine-grained sand, the average diameter of the grains being less than 0·1 mm., though some fragments are larger. The minerals are mainly quartz and hypersthene. There is much flocculent matter which encloses organic remains such as sponge spicules and, more rarely, centric diatoms.

Station **WS 77**. 12. iii. 27. Lat. 51° 01′ S. Long. 66° 31′ 30″ W. 110 m. (Plate XVIII.)

Coarse dark sand. The sample consists entirely of mineral grains up to 1 mm. in diameter. There is apparently a fair variety of minerals in rounded and subangular grains; quartz (as usual) is most abundant, but hypersthene is plentiful as worn crystals up to 0·5 mm. in length.

Station **WS 78**. 13. iii. 27. Lat. 51° 01′ S. Long. 68° 04′ 30″ W. 95 m. (Plate XVIII.)

Fine dark sand. Consists of rounded mineral grains up to 0·3 mm. in diameter, but the average is much less; the smaller grains seem to be more angular. Supernatant flocculent material.

Station **WS 79**. 13. iii. 27. Lat. 51° 01′ 30″ S. Long. 64° 59′ 30″ W. 132 m. (Plate XVIII.)

Fine dark sand. The rounded sand grains, which average about 0·2 mm. in diameter, are mostly of quartz, but hypersthene is also abundant. There is much flocculent material consisting of tiny mineral grains, navicular diatoms and sponge spicules.

Station **WS 80**. 14. iii. 27. Lat. 50° 57′ S. Long. 63° 37′ 30″ W. 152 m. (Plate XVIII.)

Fine dark sand. The deposit consists mainly of rounded mineral grains, about 0·3 mm. in diameter, but includes also many small angular grains. There is much muddy material of the usual flocculent character, which includes tiny mineral grains, sponge spicules, diatoms (centric and navicular forms) a few small Foraminifera, and probably other organic debris.

Station **WS 83**. 24. iii. 27. Lat. 52° 30′ S. Long. 60° 08′ W (approximately). 14 miles S 64° W of George Island, East Falkland Island. 137 m. (Plate XVIII.)

Sand. This sample is described in the official Station List as "fine green sand with shells". The mineral grains attain a diameter of about 0·5 mm., but most of them are much smaller; they are chiefly angular fragments of quartz, but grains of hypersthene are occasionally seen. Some opaque green grains (probably glauconite) are present, but the colour of the deposit is not entirely due to these grains; moreover the preserving liquid is coloured greenish yellow. Shelly material is present in about the same proportion as the mineral constituent. It consists mainly of microscopic lamellibranch shells mostly in a fragmentary condition; there is a variety of Foraminifera, which includes *Globigerina*, *Polystomella* and other genera. The flocculent material contains an abundance of green algal cells with mucilaginous walls; these algae apparently contribute largely to the green colour of the deposit.

Station **WS 84**. 24. iii. 27. Lat. 52° 34′ S. Long. 59° 10′ W (approximately). 7½ miles S 90° W of Sea Lion Island, East Falkland Island. 75 m. (Plate XVIII.)

COARSE SAND. A clean speckled sand with shells. The sand consists mostly of clear quartz grains about 0·5 mm. in diameter; there are some dark green grains which may be glauconite. Much shelly material is present; mainly fragments of molluscan shells, it includes also small lamellibranchs (fry), Foraminifera and echinid spines.

Station **WS 86**. 3. iv. 27. Lat. 53° 53′ 30″ S. Long. 60° 34′ 30″ W. 151 m. (Plate XVIII.)

SAND. A comparatively fine speckled sand with much shelly material, consisting of rounded or subangular grains of clear quartz and other minerals, the average diameter being about 0·2 mm. Occasional grains of hypersthene are noted. The shelly material includes fragments of lamellibranchs (many worn and rolled), echinid spines and Foraminifera. The small amount of muddy material in the sample contains centric and compound diatoms, as well as flocculent aggregates.

Station **WS 87**. 3. iv. 27. Lat. 54° 07′ 30″ S. Long. 58° 16′ 80″ W. 96 m. (Plate XVIII.)

SAND WITH SHELLS AND STONES. A speckled sand with fragments of shale and large shells, especially *Pecten*. The sand itself is largely composed of shelly material, including remains of lamellibranchs, Serpulae, Polyzoa, echinoids (spines), Foraminifera. Some detrital sand grains are present as well as the shale fragments, some of which are highly glauconitic. Supernatant flocculent material contains diatoms and possibly other small organisms.

Station **WS 88**. 6. iv. 27. Lat. 54° 00′ S. Long. 64° 57′ 30″ W. 118 m. (Plate XVIII.)

SAND. A clean speckled sand, largely composed of rounded quartz grains less than 0·5 mm. in diameter; rounded crystals of hypersthene up to 0·4 mm. in diameter are fairly common; other dark grains may be glauconite. The organic fraction includes much shelly detritus, rolled fragments of echinoid spines, and Foraminifera, many of which are not waterworn. Polyzoa also occur, encrusting small pebbles.

Station **WS 89**. 7. iv. 27. Lat. 53° 00′ S. Long. 68° 06′ W. 9 miles N 21° E of Arenas Point Light, Terra del Fuego. 23 m. (Plate XVIII.)

GRAVEL. A non-graded deposit. The largest constituents are rounded pebbles, up to 4 cm. in diameter, encrusted with Polyzoa. There are smaller pebbles from 1 cm. diameter downwards, some of quartz, others of coloured material. The sand grade contains a variety of heavy minerals. The remaining constituent is a grey slimy mud composed of flocculent aggregates with sponge spicules and tiny mineral grains.

Station **WS 90**. 7. iv. 27. Lat. 52° 18′ S. Long. 68° 00′ W. 13 miles N 83° E of Cape Virgins Light, Argentine Republic. 82 m. (Plate XVIII.)

SAND. The sample contains a large proportion of clean, rounded quartz grains, with an average diameter of about 0·3 mm.; grains of hypersthene are also fairly common. There is apparently no shelly material. The finer fraction is composed of the usual flocculent material with small quartz grains, diatoms and spicules.

Station **WS 91**. 8. iv. 27. Lat. 52° 53′ 45″ S. Long. 64° 37′ 30″ W. 191 m. (Plate XVIII.)

SAND. A clean sand with a variety of mineral grains, up to about 0·5 mm. in diameter, rounded and subangular in shape. Quartz and hypersthene are the most conspicuous minerals. Shelly material includes worn fragments of large scallop shells; a damaged simple coral is also present. There is a subordinate proportion of flocculent material.

Station **WS 92**. 8. iv. 27. Lat. 51° 58′ 30″ S. Long. 65° 01′ W. 145 m. (Plate XVIII.)

SAND. A clean sand with rounded mineral grains, the majority of which are about 0·2 mm. in diameter, though some reach 0·5 mm. Besides the predominant quartz, which is often stained, there are many opaque grains, some of which may be glauconite. Grains of hypersthene are plentiful and some worn crystals (beautifully pleochroic) reach a length of 0·5 mm. Green hornblende also is seen, though rarely. Occasional Foraminifera are noted. The finer fraction is flocculent when examined in quantity and contains extremely small mineral particles, spicules, Foraminifera and diatoms.

Station **WS 93**. 9. iv. 27. Lat. 51° 52′ 30″ S. Long. 61° 30′ W. 7 miles S 80° W of Beaver Island, West Falkland Island. 133 m. (Plate XVIII.)

SAND. A clean sand with some muddy material. The sample is rather coarser than that from the preceding station (WS 92), the rounded mineral grains reaching a diameter of 0·5 mm. or more. The sand is chiefly composed of quartz grains but also includes worn crystals of hypersthene, rounded shell fragments, Foraminifera in some abundance, and broken echinoid spines. There is a fair amount of flocculent material containing tetrad sponge spicules and diatoms.

Station **WS 94**. 16. iv. 27. Lat. 50° 00′ 15″ S. Long. 64° 57′ 45″ W. 110 m. (Plate XVIII.)

SAND. A clean sand with rounded grains, many coloured ones mingled with the predominant quartz. Grains of hypersthene are plentiful and some crystals (up to 0·5 mm. in length) are only slightly rounded. No shelly matter was seen and there is little flocculent material.

Station **WS 95**. 17. iv. 27. Lat. 48° 58′ 15″ S. Long. 64° 45′ W. 109 m. (Plate XVIII.)

SAND. The sand is clean and composed of rounded grains of quartz and coloured minerals, among which hypersthene is prominent, with an average diameter of about 0·2 mm. There are many small pebbles, but virtually no shelly matter as sand. A layer of flocculent material has separated out at the top of the sample; this is of the usual type, but centric diatoms (especially *Coscinodiscus*) are conspicuous in it.

Station **WS 96**. 17. iv. 27. Lat. 48° 00′ 45″ S. Long. 64° 58′ W. 96 m. (Plate XVIII.)

SAND. A dark, evenly graded sand, the rounded and often stained quartz grains having an average diameter of about 0·3 mm. Occasional grains of hypersthene are noted. There is no shelly material.

Station **WS 97**. 18. iv. 27. Lat. 49° 00′ 30″ S. Long. 61° 58′ W. 146 m. (Plate XVIII.)

SAND. A brownish fine-grained sand with a fair proportion of finer material. The mineral grains reach a diameter of 0·5 mm. though most are smaller; they are usually rounded and stained. Besides the preponderant quartz, grains of hypersthene are plentiful. The shelly material includes Foraminifera, broken molluscan shells and worn echinoid spines. The flocculent material consists of extremely small particles, mostly indeterminate but including some mineral grains and fragments of foraminiferal tests, also sponge spicules and elongate diatoms.

Station **WS 98**. 18. iv. 27. Lat. 49° 54′ 15″ S. Long. 60° 35′ 30″ W. 173 m. (Plate XVIII.)

SAND. A fine non-graded, dark sand with much flocculent matter containing occasional diatoms. Mineral grains reach a diameter of 0·5 mm. and grade downwards to very small dimensions. Glauconite seems to be present as internal moulds of foraminiferal shells of which one species is fairly abundant.

Station **WS 99**. 19. iv. 27. Lat. 49° 42′ S. Long. 59° 14′ 30″ W. 251 m. (Plate XVIII.)

SAND. A fine even-graded sand composed mainly of rounded quartz grains, between 0·2 and 0·1 mm. in diameter; the dark-coloured grains include some glauconite. This green material is also seen infilling the canals of broken sponge spicules. There are few foraminiferal or other shells. Some amount of flocculent material is present.

Station **WS 108**. 25. iv. 27. Lat. 48° 30′ 45″ S. Long. 63° 33′ 45″ W. 118 m. (Plate XVIII.)

SAND. A clean, evenly graded quartz sand with plentiful hypersthene and some opaque grains; the mineral fragments have an average diameter of about 0·3 mm., and are generally rounded in shape. There is a small amount of flocculent matter, but apparently no shelly material.

Station **WS 109**. 26. iv. 27. Lat. 50° 18′ 48″ S. Long. 58° 28′ 30″ W. 145 m. (Plate XVIII.)

SAND. The sample consists of clean rounded quartz grains with some sponge spicules and a little muddy material. The latter consists of extremely small flocculent particles, the aggregates of which apparently give the dark colour to the sand. Many of the mineral grains have a diameter between 0·25 and 0·5 mm. Besides quartz grains, rounded crystals of hypersthene, up to 0·5 mm. in length, are occasionally seen.

Station **WS 128–129**. 10–11. vi. 27. Between 40° 19′ S, 10° 04′ W and 40° 10′ 30″ S, 9° 40′ 45″ W. Between 2000 and 3000 m. (Plate XVII.)

GLOBIGERINA OOZE. This is a typical *Globigerina* ooze with the usual preponderance of *Globigerina* shells up to 0·5 mm. across. Some rotalines are also present. There is a small proportion of angular sand grains, some of which are 0·2 mm. in diameter. In the finer fraction, coccoliths are extremely abundant, but rhabdoliths are less plentiful.

Station **WS 201**. 22. iv. 28. Lat. 59° 57′ S. Long. 50° 12′ W. 4134 m. (Plate XVII.)

DIATOMACEOUS MUD. A small proportion of large, dark-coloured mineral grains includes volcanic glass (up to 0·5 mm. diameter), while quartz (0·2 mm.), green hornblende and a few small prismatic grains of glaucophane are noted. The larger grains are mostly well rounded. The fine-grained material which makes up the bulk of the deposit consists partly of angular mineral grains, but largely of diatom debris among which whole frustules of *Coscinodiscus*, *Cocconeis* and *Fragilaria* are abundantly represented. The mud is dark brown when wet but becomes much lighter in colour on drying, and in the almost colourless quality of the fine-grained material the deposit approaches a diatom ooze.

Station **WS 202**. 23. iv. 28. Lat. 60° 23′ S. Long. 52° 52′ W. 3987 m. (Plate XVII.)

DIATOMACEOUS MUD. The coarser fraction consists largely of mineral grains up to 0·3 mm. in diameter; it includes angular fragments of quartz, green hornblende and brown volcanic glass. The finer material is an admixture of tiny mineral grains and diatom debris among which large frustules of *Coscinodiscus* up to 0·25 mm. in diameter are conspicuous. *Triceratium*, *Biddulphia* and other centric forms, as well as *Rhizosolenia* and *Fragilaria*, are also present. Like the sample from St. WS 201, this sample approaches a diatom ooze in its light colour and in the quality of its fine-grained material.

Station **WS 203**. 25. iv. 28. Lat. 57° 42′ S. Long. 53° 12′ W. 4259 m. (Plate XVII.)

DIATOMACEOUS MUD. This sample is similar in constitution to the preceding. Some of the mineral grains are 0·3 mm. in diameter though the average is much lower; they are mostly angular in shape but some are fairly rounded. Broken diatoms provide much of the finer material, in which whole frustules of *Coscinodiscus*, *Thalassiosira* and *Fragilaria* are conspicuous. Broken tests of *Globigerina* are occasionally seen. The sample is lighter in colour than most examples of diatomaceous mud.

Station **WS 204**. 26. iv. 28. Lat. 56° 27′ S. Long. 54° 22′ W. 3328 m. (Plate XVII.)

DIATOMACEOUS MUD. This light brown mud has a considerable proportion of mineral grains which range in size from exceedingly small to about 0·1 mm. in diameter. Angular grains of quartz and green hornblende are conspicuous. The fine material consists in great part of diatom debris among which *Coscinodiscus*, *Thalassiosira* and *Fragilaria* are of common occurrence. A few broken and worn tests of *Globigerina* and Radiolaria are noted.

Station **WS 205**. 27. iv. 28. Lat. 55° 49′ S. Long. 56° 18′ W. 4207 m. (Plate XVII.)

DIATOMACEOUS MUD. This sample is essentially similar to that from St. WS 204 in general constitution. The angular mineral grains (including quartz and green hornblende) are generally small. Light-coloured flocculent aggregates which enclose the smallest mineral particles, contain broken tests of diatoms while some whole frustules of *Coscinodiscus* and *Fragilaria* are present, along with sponge spicules.

This, like the preceding three samples, is lighter in colour than most samples of diatomaceous mud, and apart from the considerable proportion of mineral grains, has almost the appearance of diatom ooze.

Station **WS 255**. 22–23. viii. 28. Lat. 53° 23′ S. Long. 44° 10′ W. 3003 m. (Plate XVII.)

DIATOM OOZE. The bulk of this light-coloured mud is composed of diatom frustules. In the considerable variety of forms, the genera *Coscinodiscus*, *Thalassiosira*, *Cocconeis*, *Fragilaria*, *Thalassiothrix* and *Rhizosolenia* are noted. Sponge spicules and Radiolaria are represented, the latter by occasional nasselarian forms. There is a small proportion of quartz grains, mostly below 0·05 mm. in diameter.

Station **WS 314**. 1. xii. 28. Lat. 53° 36′ S. Long. 41° 05′ W. 137 m. (Plate XVII.)

SAND. The most interesting feature of this extremely small sample of sand is the large proportion of colourless flakes up to 0·2 mm. in diameter, some of which show a sharp, unworn, hexagonal outline; some show a radial texture and are evidently zeolitic aggregates. A few diatoms are present, among which *Coscinodiscus* and *Fragilaria* are noted. There is some evidence of ferruginous cementation.

Station **WS 317**. 4. xii. 28. Lat. 52° 41′ S. Long. 49° 39′ 30″ W. 3369 m. (Plate XVII.)

GRAVEL. The sample consists of a few small black pebbles. The label states, "It is probable that the finer constituents of the sample were washed out, and the coarse only retained".

Station **WS 319**. 5. xii. 28. Lat. 52° 01′ S. Long. 54° 52′ W. 1602 m.

GRAVEL AND COARSE SAND. A small sample concerning which the Station List notes "finer material from bottom sample washed out". It contains a few tests of *Globigerina*, some small pebbles, and a little coarse sand. The latter includes some dark opaque grains (up to 1 mm. diameter), rounded and lobate in shape; when crushed they show the optical characters of glauconite. As the sample is incomplete the station has not been entered on Plate XVII.

Station **WS 374**. 6–7. ii. 29. Lat. 55° 09′ S. Long. 40° 00′ W. 3226 m. (Plate XVII.)

DIATOM OOZE. A brownish deposit with some admixture of mineral grains, but a fairly typical diatom ooze. The diatoms include species of *Coscinodiscus*, *Fragilaria*, *Thalassiothrix* and *Rhizosolenia*. A few tests of *Globigerina* and Radiolaria are present.

Station **WS 377**. 9. ii. 29. Lat. 58° 34′ S. Long. 44° 47′ W. 2552 m. (Plate XVII.)

DIATOM OOZE. The mineral constituent in this brown mud is very small, consisting of angular grains which are usually much smaller in diameter than the maximum of 0·1 mm. Diatoms make up the bulk of the deposit, occurring in some variety as whole frustules and also as broken material in all stages of disintegration. *Coscinodiscus*, *Fragilaria*, *Rhizosolenia* and *Thalassiothrix* are most abundant, while *Thalassiosira* and *Asteromphalus* occur more rarely. Occasional fragments of Radiolaria and Foraminifera are noted.

Station **WS 381**. 14. ii. 29. Lat. 61° 26′ S. Long. 56° 19′ W. 425 m. (Plate XVII.)

COARSE SAND. This small sample contains mineral grains up to 1 mm. in diameter, all fairly angular in shape. Quartz, green hornblende and volcanic glass are represented, as well as smaller grains of phillipsite which often occurs as cross-twin or flat, hexagonal crystals. The sample is almost free of organic debris, only a few diatoms being noted.

Station **WS 382**. 15. ii. 29. Lat. 62° 15′ 35″ S. Long. 58° 18′ 30″ W. 425 m. (Plate XX.)

TERRIGENOUS MUD. The coarse fraction consists almost entirely of mineral grains, the size of which ranges downwards from about 0·2 mm. in diameter. The finer material comprises exceedingly small mineral grains together with some indefinite flocculent aggregates. Recognizable organic remains are scanty, but include diatoms (*Coscinodiscus* and *Fragilaria*) and sponge spicules.

Station **WS 383**. 15. ii. 29. Lat. 62° 20′ 40″ S. Long. 58° 13′ W. 2085 m. (Plate XX.)

DIATOMACEOUS MUD. This dark, greenish brown mud is finer in grain than the last, and contains more diatom frustules. Among the latter *Coscinodiscus*, *Thalassiosira*, *Cocconeis*, *Fragilaria*, *Corethron* and *Rhizosolenia* are noted. Some retain their protoplasmic content which is similar in appearance to the fine-grained flocculent material. The mineral grains (chiefly subangular fragments of quartz) range downwards from a diameter of about 0·1 mm.

Station **WS 384**. 15. ii. 29. Lat. 62° 25′ 40″ S. Long. 58° 06′ 10″ W. 1957 m. (Plate XX.)

DIATOMACEOUS MUD. This sample shows close resemblance in general characters to that from St. WS 383. The assemblage of diatoms contains the same genera, but the great abundance of large and well-developed frustules of *Corethron* and *Rhizosolenia* is worthy of special mention.

Station **WS 385**. 16. ii. 29. Lat. 62° 32′ S. Long. 57° 55′ W. 1838 m. (Plate XX.)

DIATOMACEOUS MUD. This sample is typical of its kind, and differs in no essential particular from those last described. It contains the same assemblage of diatoms, namely *Coscinodiscus*, *Thalassiosira*, *Cocconeis*, *Fragilaria*, *Corethron* and *Rhizosolenia* in quantity. The protoplasmic contents of some diatoms are seen within the valves, and appear to contribute to the flocculent aggregates. The preserving liquid is tinted green. The average size of the sand grains is perhaps smaller than in the preceding samples.

Station **WS 386**. 16. ii. 29. Lat. 62° 41′ S. Long. 57° 44′ W. 1392 m. (Plate XX.)

DIATOMACEOUS MUD. The largest sand grains in this sample attain a diameter of 0·3 mm. and grade downwards in size. The proportion of large grains, however, is not sufficient materially to affect the general constitution of the deposit which is closely similar to those from preceding stations. The diatoms include species of *Coscinodiscus*, *Thalassiosira*, *Cocconeis*, *Fragilaria*, *Rhizosolenia* and *Corethron*.

Station **WS 387**. 16. ii. 29. Lat. 62° 49′ S. Long. 57° 40′ W. 640 m. (Plate XX.)

DIATOMACEOUS MUD. This sample is much coarser in grain than the preceding, many of the angular mineral grains reaching a diameter of 0·5 mm., though the average is much less. Occasional grains of a glauconitic mineral are noted. The mineral content is perhaps larger in proportion than in the former samples, but the diatomaceous material is still important. The genera *Coscinodiscus*, *Thalassiosira*, *Cocconeis*, *Fragilaria*, *Corethron* and *Rhizosolenia* are present in quantity, along with sponge spicules. The preserving liquid is coloured green and many of the diatoms retain their organic content.

Station **WS 388**. 16. ii. 29. Lat. 62° 55′ 30″ S. Long. 57° 40′ W. 446 m. (Plate XX.)

DIATOMACEOUS MUD(?). This sample consists only of a small quantity of mud and a few small pebbles. As green mud is also recorded in the Station List, the sample seems to be incomplete, and it can only be said that the small quantity of fine material available resembles a diatomaceous mud.

Station **WS 389**. 16. ii. 29. Lat. 63° 17′ S. Long. 58° 51′ 05″ W. 130 m. (Plate XX.)

SAND. Many of the mineral grains in this sample reach a diameter of 0·5 mm. and the deposit is not coherent. As a rule the grains of volcanic glass are somewhat angular in shape while those of quartz are somewhat rounded. Diatom frustules are present in the fine-grained flocculent material, but mainly in a broken condition; some undamaged valves of *Coscinodiscus*, *Cocconeis* and *Biddulphia* are noted.

Station **WS 391**. 17. ii. 29. Lat. 63° 02′ S. Long. 59° 12′ W. 877 m. (Plate XX.)

DIATOMACEOUS MUD. The bulk of the deposit consists of diatom frustules and small mineral grains, in a "matrix" of flocculent material. The chief genera of diatoms are: *Coscinodiscus*, *Thalassiosira*, *Triceratium*, *Cocconeis*, *Fragilaria*, *Thalassiothrix*, *Corethron* and *Rhizosolenia*. While the great majority of the mineral grains are less than 0·1 mm. across, some reach a diameter of about 0·5 mm. The largest are angular fragments of brown volcanic glass; quartz grains are smaller and more rounded.

Station **WS 392**. 17. ii. 29. Lat. 62° 52′ S. Long. 59° 26′ W. 591 m. (Plate XX.)

DARK SAND. This small sample consists of sand, dark-coloured from the abundance of opaque grains of volcanic glass which reach 0·25 mm. in diameter. Grains of quartz occur but sparingly. Zeolitic aggregates are also noted.

Station **WS 393**. 17–18. ii. 29. Lat. 62° 41′ S. Long. 59° 41′ W. Three samples from depths of 900–1000, 1051 and 1138 m. (Plate XX.)

DIATOMACEOUS MUD. The three samples are very similar in character and are typical of diatomaceous mud. The usual flocculent material encloses angular sand grains (mostly below 0·05mm. in diameter) and a variety of diatoms. The genera *Coscinodiscus*, *Thalassiosira*, *Cocconeis*, *Fragilaria*, *Corethron* and *Rhizosolenia* are the most conspicuous forms. In detail the samples show noteworthy differences. The largest mineral grains are noted in the sample from 1138 m., in which grains with a diameter of 0·5 mm. are noted, while mineral fragments up to 0·2 mm. are common at the intermediate depth. Nearly all the grains are sharply angular, and many of them are splinters of volcanic glass.

Station **WS 394**. 18. ii. 29. Lat. 62° 51′ S. Long. 60° 40′ W. 274 m. (Plate XX.)

TERRIGENOUS MUD. The bulk of this sample consists of mineral grains, mostly angular in shape, and ranging downwards in size from a diameter of about 0·25 mm., the average being roughly 0·05 mm. Among the mineral material are grains of quartz and vesicular volcanic glass, and occasional small grains of glaucophane. There is a considerable amount of fine, flocculent matter which contains some frustules of *Coscinodiscus* and *Fragilaria*. The diatoms are not plentiful, hence this deposit is classed as terrigenous mud.

Station **WS 395**. 19. ii. 29. Lat. 63° 48′ 30″ S. Long. 62° 26′ W. 297 m. (Plate XX.)

DIATOMACEOUS MUD. This sample is a typical diatomaceous mud. The mineral grains are small, mostly less than 0·05 mm. in diameter, though some are 0·1 mm. across. Green hornblende, hypersthene (0.1 mm.) and glaucophane (0·1 mm.) are present, as well as fragments of volcanic glass. Diatoms are present in some abundance, the largest being species of *Coscinodiscus* and *Triceratium* with a diameter of about 0·2 mm. The genera *Thalassiosira*, *Cocconeis*, *Fragilaria*, *Corethron* and *Rhizosolenia* are also represented. A single example of a sphaeroid radiolarian is noted.

Station **WS 396**. 19. ii. 29. Lat. 63° 38′ 30″ S. Long. 62° 28′ 30″ W. 318 m. (Plate XX.)

DIATOMACEOUS MUD. The coarser fraction contains angular mineral grains, some of them more than 0·25 mm. in diameter, but the great majority are much smaller. Grains of quartz, green hornblende and glaucophane are fairly common in occurrence together with splinters of volcanic glass. Diatom frustules are plentiful in the finer fraction, *Coscinodiscus*, *Thalassiosira*, *Asteromphalus*, *Cocconeis* and *Fragilaria* being the most abundant genera. Rotaline Foraminifera are occasionally seen. The flocculent material is of the usual type.

Station **WS 397**. 19. ii. 29. Lat. 63° 29′ 25″ S. Long. 62° 37′ W. 150 m. (Plate XX.)

SAND. This sample is a small quantity of clean sand of which the grains are mainly between 0·25 and 0·05 mm. in diameter. Subangular to rounded in shape, the majority are quartz grains, but some are opaque. Several grains of glaucophane are noted, but the sample is too small for any judgment to be pronounced on its relative abundance in the deposit.

Station **WS 399**. 20. ii. 29. Lat. 62° 50′ S. Long. 61° 58′ 30″ W. 738 m. (Plate XX.)

SAND. Two fractions are somewhat sharply differentiated in this small sample. The coarser constituents are mineral grains varying between 0·5 and 0·1 mm. in diameter. Some angular grains are fragments of brown volcanic glass, which is sometimes vesicular in character. There are also occasional grains of glaucophane. The finer fraction consists largely of small angular fragments of quartz mingled with flocculent material in which some diatoms are present. *Coscinodiscus*, *Biddulphia*, *Fragilaria* and *Rhizosolenia* are the genera noted.

Station **WS 400**. 21. ii. 29. Lat. 62° 07′ S. Long. 62° 33′ W. 4517 m. (Plate XX.)

DIATOMACEOUS MUD. This brownish grey mud contains a considerable proportion of inorganic material, unworn and angular mineral grains varying from 0·1 mm. in diameter to exceedingly small dimensions. Besides quartz, grains of green hornblende, glaucophane and hypersthene are noted, some of the latter showing crystal faces. There is much flocculent material which consists largely of broken frustules of diatoms in all stages of disintegration. Whole frustules of *Coscinodiscus*, *Thalassiosira*, *Cocconeis* and *Fragilaria* are of common occurrence.

Station **WS 403**. 22–23. ii. 29. Lat. 59° 41′ S. Long. 64° 35′ W. 3721 m. (Plate XVII.)

DIATOMACEOUS MUD. The coarser fraction contains mineral grains up to 0·1 mm., mostly angular in condition; quartz, green hornblende and occasional grains of glaucophane are among the minerals present. There is also some quantity of large tests of *Globigerina* and rotaline Foraminifera, together with radiolarian tests. The finer fraction consists of flocculent material which includes whole and broken frustules of diatoms, *Coscinodiscus*, *Fragilaria*, *Cocconeis*, *Thalassiothrix* being prominent genera.

This sample is not easy to classify. The coarse washing might almost be a *Globigerina* ooze, but the proportion of mineral grains is too large. The finer material, which forms the greater proportion of the deposit, has the typical constitution of diatomaceous mud. The deposit is therefore classified as such, despite the unusual abundance of Foraminifera.

Station **WS 406**. 24. ii. 29. Lat. 56° 50′ 30″ S. Long. 67° 03′ W. 1234 m. (Plate XVII.)

FORAMINIFERAL SAND. The sample is a small quantity of sand which consists of quartz grains and tests of Foraminifera. Among the latter *Globigerina* together with rotalines and textularians are plentiful.

Station **WS 428**. 29. vi. 29. Lat. 53° 07′ S. Long. 42° 30′ W. 1966 m. (Plate XVII.)

DIATOMACEOUS MUD. There is a considerable proportion of diatomaceous debris containing entire frustules of *Coscinodiscus*, *Cocconeis*, *Fragilaria* and *Thalassiothrix*, together with sponge spicules and occasional radiolarian tests. The finer particles form flocculent aggregates. The grains of the mineral constituents vary in diameter from 0·25 mm. down to exceedingly small dimensions, and are generally angular or subangular in shape. Most of the colourless fragments are of quartz, and some of the opaque grains appear to be glauconite.

Station **WS 429**. 30. iv. 29. Lat. 53° 02′ 30″ S. Long. 45° 28′ W. 2549 m. (Plate XVII.)

DIATOM OOZE. This is a typical diatom ooze, formed almost entirely of frustules among which species of *Coscinodiscus*, *Thalassiosira*, *Cocconeis*, *Achnanthes*, *Rhizosolenia* and *Thalassiothrix* are noted. Fragments of radiolarian tests are also present. Mineral grains occur in small quantity; they are mostly very small but occasionally grains of quartz and prisms of hornblende reach a length of 0·1 mm.

Station **WS 433**. 5–6. v. 29. Lat. 51° 44′ S. Long. 56° 23′ W. 1035 m. (Plate XVII.)

GLAUCONITIC MUD. The sediment has formed layers in the storage bottle, dark sand below, light brown mud above, and the liquid is coloured green. The coarser fraction consists of mineral grains up to 0·25 mm. across. Many of these are rounded grains of glauconite, some of them infilling broken foraminiferal tests; there are, however, many shells which do not contain glauconite. Grains of quartz and hornblende are also noted. Foraminifera are represented by *Globigerina* and rotalines. The finer fraction consists of small mineral grains, broken sponge spicules and flocculent matter.

Station **WS 468**. 9–10. xi. 29. Lat. 55° 52′ S. Long. 56° 53′ W. 4344 m. (Plate XVII.)

DIATOMACEOUS MUD. This deposit contains a large proportion of mineral grains, some of which reach a diameter of 0·2 mm. Quartz and green hornblende are conspicuous in angular grains, but some fragments are well rounded. Occasional grains of garnet are noted. The finer material consists of organic debris, sponge spicules and diatom frustules; most of the latter are fragmentary, but some whole frustules of *Coscinodiscus* occur. Broken tests of *Globigerina* are present.

Station **WS 485**. 21. xi. 29. Lat. 63° 02½′ S. Long. 59° 17′ W. 805 m. (Plate XX.)

Diatomaceous mud. This greenish deposit agrees so closely with that from St. WS 484 that the same description applies.

Station **WS 486**. 21. xi. 29. Lat. 63° 11½′ S. Long. 59° 13′ W. 787 m. (Plate XX.)

Diatomaceous mud. Closely similar to the foregoing.

Station **WS 487**. 22. xi. 29. Lat. 63° 17′ S. Long. 59° 20′ W. 790 m. (Plate XX.)

Diatomaceous mud. This also agrees with the last three samples.

Station **WS 488**. 22. xi. 29. Lat. 63° 51½′ S. Long. 62° 31′ W. 220 m. (Plate XX.)

Terrigenous mud. The character of this deposit is given by its inorganic constituent. The mineral grains range in size from about 0·5 mm. downwards to exceedingly small dimensions. The larger grains are fairly well rounded, but a large proportion of the smaller grains are angular. Apart from quartz, green hornblende seems to be the most abundant mineral; hypersthene and glaucophane also occur, but the last named only rarely. Organic remains, present only in subordinate quantity, include sponge spicules and diatoms; among the latter *Coscinodiscus*, *Cocconeis*, *Thalassiosira* and *Fragilaria* are noted.

Station **WS 489**. 22. xi. 29. Lat. 63° 38′ S. Long. 62° 32′ W. 308 m. (Plate XX.)

Diatomaceous mud. This is a greenish grey mud which contains the usual admixture of diatom debris and mineral grains. The latter are mainly angular in shape, and apart from the ubiquitous quartz (up to 0·1 mm. diameter) include green hornblende (0·05 mm.) and rich blue glaucophane (0·1 mm.) in some abundance; the last-named mineral shows the characteristic pleochroism (violet to blue). The diatoms include *Coscinodiscus* (up to 0·25 mm. across) *Thalassiosira*, *Cocconeis*, *Fragilaria*, *Rhizosolenia*. Textularian Foraminifera and sponge spicules are also noted.

Station **WS 490**. 22. xi. 29. Lat. 63° 24½′ S. Long. 62° 35½′ W. 262 m. (Plate XX.)

Sand. This greyish deposit is best classed as a sand, though it contains a fair quantity of fine-grained flocculent material. The bulk of the sample consists of quartz grains ranging downwards in size from a diameter of about 0·5 mm. Occasional pleochroic prisms of glaucophane (0·1 mm. long) and green hornblende (0·2 mm. maximum) are noted and doubtless other minerals are present. Sponge spicules and diatoms occur, but are not sufficiently abundant to give character to the deposit.

Station **WS 493**. 23. xi. 29. Lat. 62° 51′ S. Long. 60° 34′ W. 220 m. (Plate XX.)

Sand. This is a dark-coloured sand, with grains from 0·5 to 0·05 mm. in diameter, the average being about 0·25 mm. Most of the grains are brown in colour by transmitted light and isotropic between crossed nicols; they are sharply angular fragments of glassy and vesicular volcanic material. There is only a small proportion of rounded quartz grains.

Station **WS 494**a. 28. xi. 29. Lat. 63° 15′ S. Long. 61° 05′ W. 1035 m. (Plate XX.)

Sand. The character of the detrital material outweighs in importance the organic constituent, and the size of the grains determines the classification of this sample as a sand. The mineral grains include angular and subangular fragments of quartz (up to 0·3 mm. diameter), sharply angular splinters of volcanic glass (up to 0·5 mm.), occasional grains of green hornblende (0·15 mm.) and glaucophane (0·2 mm.). The fine-grained flocculent material encloses frustules of *Coscinodiscus*, *Cocconeis*, *Fragilaria* and *Rhizosolenia*.

Station **WS 494**b. 28. xi. 29. Lat. 63° 37½′ S. Long. 61° 16′ W. 505 m. (Plate XX.)

Sand. This is a greenish sandy deposit which owes its colour to the fine-grained flocculent constituent, which is largely diatomaceous in character. The bulk of the deposit, however, consists of mineral grains up to 0·5 mm. in diameter. Angular and rounded grains of quartz, sharp splinters of volcanic glass, and prismatic grains of green hornblende (0·25 mm. long) are abundant, while occasional small grains of glaucophane occur.

Station **WS 495**. 22. xii. 29. Lat. 67° 47′ S. Long. 73° 51′ W. 2582 m. (Plate XXI.)

DIATOMACEOUS MUD. This is a brownish mud formed largely of flocculent material which encloses diatom frustules and mineral grains. The latter are mostly below 0·05 mm. in diameter, though some reach 0·2 mm. Rounded and subangular grains of quartz are most abundant, while green hornblende and white mica are also noted. The chief diatom genera are *Coscinodiscus* and *Fragilaria*. Some tests of Radiolaria include *Sethoconus* and fragments of other genera.

Station **WS 496**. 30. xii. 29. Lat. 67° 14′ S. Long. 70° 12′ W. 631 m. (Plate XXI.)

DIATOMACEOUS MUD. An unctuous green-grey mud, composed largely of diatom debris, among which undamaged frustules of *Coscinodiscus*, *Thalassiosira*, *Fragilaria*, *Cocconeis*, *Corethron* (often with chloroplasts) and *Biddulphia* are plentiful. A few Radiolaria and sponge spicules are noted. There is a fair proportion of mineral grains, mostly subangular in shape, up to 0·1 mm. in diameter, including quartz, white mica and green hornblende.

Station **WS 497**. 1. i. 30. Lat. 67° 05′ S. Long. 70° 40′ W. 534 m. (Plate XXI.)

DIATOMACEOUS MUD. A grey unctuous mud with the same general characters as the preceding sample. The diatoms include *Coscinodiscus*, *Thalassiosira*, *Fragilaria*, *Rhizosolenia*, *Cocconeis* and *Biddulphia*. A few Radiolaria and rotaline Foraminifera are seen. Mineral grains reach a diameter of about 0·15 mm. and include subangular fragments of quartz with some prismatic grains of green hornblende.

Station **WS 498**. 2–3. i. 30. Lat. 66° 21′ S. Long. 69° 01′ W. 398 m. (Plate XXI.)

SAND. The mineral grains in the coarser fraction reach a diameter of about 0·5 mm. Angular grains of quartz predominate over prisms of green hornblende, grains of hypersthene and fragments of volcanic glass. Flocculent material is almost equal in bulk and includes diatom remains; but only frustules of *Fragilaria* are identified.

Station **WS 499**. 3. i. 30. Lat. 65° 45′ S. Long. 67° 18′ W. 179 m. (Plate XXI.)

SAND. The mineral grains range downwards in size from about 0·25 mm. in diameter. They include subangular grains of quartz, green hornblende and pink garnet. The fine-grained flocculent material is largely diatomaceous in origin; the chief genera are: *Coscinodiscus*, *Fragilaria*, *Biddulphia*, *Cocconeis*, *Thalassiosira* and *Corethron*.

Station **WS 501**. 3. i. 30. Lat. 64° 52′ S. Long. 63° 58′ W. 583 m. (Plate XXI.)

DIATOMACEOUS MUD. This greenish mud consists largely of flocculent aggregates formed of diatoms in all stages of disintegration along with other organic debris; the liquid also is coloured green. Whole frustules of the genera *Triceratium* (0·5 mm. across), *Coscinodiscus*, *Thalassiosira*, *Fragilaria*, *Cocconeis*, *Corethron* are plentiful. Mineral grains form a subordinate proportion of the deposit; they are chiefly of quartz, but occasional grains of green hornblende and possibly of chlorite also occur. The grains are mainly below 0·05 mm. in diameter, but some fragments are 0·2 mm. across.

Station **WS 502**. 30. i. 30. Lat. 69° 43′ S. Long. 99° 38′ W. 4224 m. (Plate XXI.)

DIATOMACEOUS MUD. This sample, brown in colour, is composed mainly of flocculent material of the usual appearance. It contains whole frustules of *Fragilaria* and *Coscinodiscus*, together with fragments of Radiolaria. Mineral grains of varying size (0·2 mm. to less than 0·01 mm. in diameter) consist chiefly of angular and rounded fragments of quartz with occasional grains of green hornblende.

Station **WS 503**. 30. i. 30. Lat. 70° 03½′ S. Long. 100° 39′ W. 4072 m. (Plate XXI.)

TERRIGENOUS MUD. The sample is grey and coherent when dry. It consists largely of angular or subangular mineral grains up to about 0·2 mm. in diameter. Quartz is most abundant, and some grains show undulose extinction in polarized light. Fragments of green hornblende are not uncommon. There is some amount of flocculent material which forms aggregates enclosing mineral grains, but the sample is singularly deficient in recognizable organic remains, except for a few sponge spicules and frustules of *Coscinodiscus* which have an eroded appearance.

Station **WS 505**. 4. ii. 30. Lat. 70° 10½′ S. Long. 87° 46′ W. 1500 m. (Plate XXI.)

Terrigenous mud. A brown mud composed of flocculent matter which encloses mineral grains. The grains grade downwards in size from a diameter of about 0·1 mm.; they are fairly angular in shape and consist chiefly of quartz with occasional fragments of green hornblende. There are few recognizable organisms, only a few tests of *Cristellaria* and fragments of *Globigerina* being noted.

Station **WS 506**. 7. ii. 30. Lat. 70° 31′ S. Long. 81° 36′ W. 584 m. (Plate XXI.)

Terrigenous mud. A brown unctuous mud with the same general characters as the preceding sample.

Station **WS 507A**. 8. ii. 30. Lat. 70° 32½′ S. Long. 81° 42′ W. 572 m. (Plate XXI.)

Terrigenous mud. This sample resembles those from Sts. WS 505 and WS 506. The bulk of the mineral grains are less than 0·01 mm. in diameter, but some larger grains (0·1 mm.) are of quartz and green hornblende. The flocculent material encloses diatoms (frustules of *Coscinodiscus*), but they are not plentiful.

Station **WS 507B**. 8. ii. 30. Lat. 70° 34′ S. Long. 81° 55′ W. 580 m. (Plate XXI.)

Terrigenous mud. This deposit is closely similar to the last in general constitution. The larger mineral grains (0·1 mm. diameter) include quartz and green hornblende. Frustules of *Coscinodiscus*, enclosed in flocculent aggregates, still retain their cell contents.

Station **WS 508**. 10. ii. 30. Lat. 69° 04′ S. Long. 77° 40′ W. 309 m. (Plate XXI.)

Fine gravel. The sample consists of a few small rounded pebbles, about 5 mm. in diameter.

Station **WS 509**. 11. ii. 30. Lat. 67° 18′ S. Long. 69° 28′ W. 445 m. (Plate XXI.)

Diatomaceous mud. The flocculent material in this sample is definitely diatomaceous. It contains many frustules of *Coscinodiscus*, *Cocconeis*, *Thalassiosira* and *Fragilaria* which are rather small, but also larger ones (including *Triceratium*) which retain their cell contents. The mineral grains, ranging downwards in size from 0·2 mm. in diameter, include angular fragments of quartz and green hornblende.

Station **WS 510**. 11. ii. 30. Lat. 67° 11′ S. Long. 69° 46′ W. 505 m. (Plate XXI.)

Diatomaceous mud. This is a green-grey mud in which flocculent diatomaceous material is dominant, and many of the frustules still enclose greenish cell contents. The chief genera are *Coscinodiscus*, *Fragilaria*, *Thalassiosira* and *Cocconeis*. The mineral constituent consists mainly of subangular grains of quartz (up to 0·1 mm. diameter) with occasional prismatic grains of green hornblende.

Station **WS 511**. 11. ii. 30. Lat. 67° 04′ S. Long. 70° 04′ W. 635 m. (Plate XXI.)

Diatomaceous mud. A greenish grey mud which is mainly flocculent diatom debris. Whole frustules of *Coscinodiscus* (0·2 mm.), *Thalassiosira*, *Fragilaria*, *Cocconeis* and *Corethron* occur along with sponge spicules. Mineral grains (quartz and green hornblende) are usually angular and very small, but some reach a diameter of 0·05 mm.

Station **WS 512**. 11. ii. 30. Lat. 66° 57′ S. Long. 70° 22′ W. 652 m. (Plate XXI.)

Diatomaceous mud. Flocculent diatom debris makes up the bulk of this greenish grey mud, in which whole frustules of *Coscinodiscus*, *Cocconeis*, *Fragilaria*, *Rhizosolenia* and *Thalassiosira* are noted. There is a subordinate proportion of subangular mineral grains, mostly less than 0·05 mm. in diameter, among which quartz and green hornblende are recognized.

Station **WS 513**. 11. ii. 30. Lat. 66° 49½′ S. Long. 70° 40½′ W. 560. m. (Plate XXI.)

Diatomaceous mud. A greenish mud of the same type as the preceding sample. Frustules of *Coscinodiscus*, *Thalassiosira*, *Cocconeis*, *Biddulphia*, *Fragilaria*, *Corethron* and *Rhizosolenia* are noted. Quartz grains form the greater part of the mineral fraction, while green hornblende also is present.

Station **WS 514**. 11. ii. 30. Lat. 66° 40½′ S. Long. 71° 01′ W. 531 m. (Plate XXI.)

DIATOMACEOUS MUD. The sample contains flocculent material of the same type as the foregoing sample but less abundantly. It encloses frustules of *Coscinodiscus*, *Thalassiosira*, *Biddulphia* and *Fragilaria*. The mineral grains attain a larger size, angular grains of quartz and green hornblende reaching 0·2 mm., and dark opaque grains 0·25 mm. in diameter.

Station **WS 515**. 11. ii. 30. Lat. 66° 3½′ S. Long. 71° 20½′ W. 512 m. (Plate XXI.)

DIATOMACEOUS MUD. The deposit is of the same type and contains the same diatoms as the preceding samples. Mineral grains are perhaps more abundant; angular grains of quartz reach 0·2 mm. and green hornblende 0·1 mm. in diameter.

Station **WS 516**. 12. ii. 30. Lat. 66° 25½′ S. Long. 71° 38½′ W. 2611 m. (Plate XXI.)

SAND. The sample has separated into layers during storage, brown mud above, and dark-coloured sand below.

The former consists of tiny mineral grains usually less than 0·01 mm. in diameter, together with plentiful tests of Radiolaria, occasional whole frustules of diatoms, and a fair proportion of fragmentary tests. The coarser fraction contains mineral grains up to 1 mm. in diameter, chiefly angular grains of quartz and opaque rock fragments. These give character to the deposit which must be classed as a sand.

Station **WS 517**. 12. ii. 30. Lat. 66° 17½′ S. Long. 71° 57′ W. 2770 m. (Plate XXI.)

DIATOMACEOUS MUD. This brown mud consists largely of detrital mineral grains, which are mostly below 0·05 mm. in diameter though occasional grains are 0·25 mm. across. Angular fragments of quartz (up to 0·25 mm.) and prismatic grains of green hornblende (0·1 mm. long) are the most abundant minerals. The finer fraction contains a large proportion of tiny angular grains, mingled with flocculent material which consists partly of diatom debris. Recognizable organic remains are not abundant, but they include the diatoms *Fragilaria*, *Cocconeis* and *Coscinodiscus*, along with fragments of radiolarian tests. The diatomaceous material is sufficiently important to be taken into account with the mineral content in classifying this deposit.

Station **518**. 27. ii. 30. Lat. 51° 55½′ S. Long. 55° 35′ W. 1258 m. (Plate XVII.)

GLAUCONITIC MUD. This is a greyish deposit with dark-coloured sand grains. The coarser fraction consists of foraminiferal shells, fragments of quartz and grains of glauconite. The latter reach a diameter of about 0·5 mm., and they retain the shape of foraminiferal tests which they once infilled; *Globigerina* and textularian forms are represented, and portions of the shell still adhere to some of the grains. The quartz grains are usually smaller. Unbroken tests of *Globigerina*, *Orbulina* and rotalines are plentiful. The finer fraction consists of comminuted foraminiferal shells together with tiny quartz grains, broken sponge spicules and occasional Radiolaria, the whole often forming flocculent aggregates.

Station **WS 520**. 27–28. ii. 30. Lat. 52° 25′ S. Long. 51° 20′ W. 3128 m. (Plate XVII.)

GLOBIGERINA OOZE. A small quantity of light-coloured deposit with dark grains. The bulk of the sample consists of well-developed tests of *Orbulina* and *Globigerina*, up to 0·1 mm. in diameter, many of which are undamaged. The dark grains, with the same average diameter, are glauconitic moulds of *Globigerina* from which the shell has dissolved; the septa of the test remain, however, so that the mould can be identified. There are also angular grains of quartz which are usually smaller than the Foraminifera. The small proportion of flocculent matter consists of coccoliths, rhabdoliths, and tiny fragments of disintegrated *Globigerina* shells, the aggregates often enclosing small mineral grains.

Station **WS 521**. 28. ii. 30. Lat. 52° 41′ S. Long. 49° 14′ W. 3780 m. (Plate XVII.)

GLOBIGERINA OOZE. This is similar in general characters to the preceding sample, but the proportion of mineral grains is larger. Many of the grains reach a diameter of 0·1 mm., while a few are 0·4 mm. across. The proportion of fine flocculent material is perhaps greater than in the former sample and a few diatoms are present.

Station **WS 522**. 28. ii–1. iii. 30. Lat. 52° 56′ S. Long. 47° 14′ W. 2550 m. (Plate XVII.)

Globigerina ooze. The coarser fraction, which constitutes the bulk of the deposit, has the characters of a *Globigerina* ooze, with some admixture of terrigenous material. Some sand grains are 0·5 mm. in diameter; the minerals represented include angular fragments of quartz and red garnet, and some opaque grains of glauconite with rounded and lobate outlines. There are also a few small pebbles, 1 cm. across. The finer material has a fair proportion of diatom frustules (*Coscinodiscus*, *Fragilaria*, *Rhizosolenia*), with coccoliths and occasional fragments of Radiolaria. A few cross-twins of the mineral phillipsite are noted.

The main character of the deposit is given by the comparatively large and abundant calcareous organisms, and hence it is classed as *Globigerina* ooze.

Station **WS 524**. 2. iii. 30. Lat. 53° 36′ S. Long. 43° 00′ W. 1697 m. (Plate XVII.)

Diatomaceous mud. The coarser fraction contains most of the mineral grains, while the finer material is almost entirely composed of diatom frustules. The latter are present in some variety, *Coscinodiscus*, *Arachnoidiscus*, *Thalassiosira*, *Fragilaria*, *Rhizosolenia* and *Thalassiothrix* being the chief genera represented. The mineral grains are subangular to rounded in shape and the great majority are about 0·1 mm. in diameter; quartz (0·2 mm.), green hornblende and felspar are noted. A few tests of *Globigerina* also occur in the coarser material.

Station **WS 525**. 2. iii. 30. Lat. 53° 38½′ S. Long. 41° 09′ W. 162 m. (Plate XVII.)

Gravel (?). The sample consists only of a few small pebbles and grains of quartz.

Station **WS 526**. 3. iii. 30. Lat. 53° 51′ S. Long. 39° 45′ W. 1545 m. (Plate XVII.)

Diatomaceous mud. This greenish mud owes its colour to the presence of green flocculent matter of organic origin; the preserving liquid has acquired a green tinge. There is a variety of diatom frustules including species of *Coscinodiscus*, *Fragilaria*, *Biddulphia*, *Rhizosolenia* and *Thalassiothrix*. A few nasselarian Radiolaria are noted. The coarser fraction consists mainly of subangular quartz grains up to about 0·1 mm. diameter.

Station **WS 591**. 18. v. 31. Lat. 35° 47′ S. Long. 72° 39′ W. 27 m. (Plate XXII.)

Sand. This is a "Bottom sample from armed lead", consisting of a small quantity of sand, the grains of which average about 0·3 mm. in diameter. The material includes grains of hypersthene (0·3 mm.), besides quartz and opaque grains; these are mostly angular or only slightly rounded. There is no fine-grained material.

Station **WS 596**. 18. v. 31. Lat. 35° 35′ 36″ S. Long. 73° 07′ 30″ W. 369 m. (Plate XXII.)

Terrigenous mud. This dark green deposit has layered out during storage. The coarser fraction consists of mineral grains which average about 0·2 mm. in diameter; they are mainly angular fragments of quartz, but some are grains of hypersthene and green hornblende. The finer fraction is a flocculent material of rather granular appearance which remains suspended in the green liquid for some considerable time after disturbance. No organisms are recognized except sponge spicules, but the flocculent material generally resembles organic debris; it encloses tiny mineral grains. The detrital mineral constituent gives the main character to the deposit.

Station **WS 597**. 19. v. 31. Lat. 35° 39′ 42″ S. Long. 73° 19′ 30″ W. 1593 m. (Plate XXII.)

Terrigenous mud. A dark green mud, consisting of somewhat granular flocculent matter, in clots of which small sand grains are embedded. The latter are mostly less than 0·05 mm., but occasionally angular grains of quartz and green hornblende reach a diameter of 0·1 mm. There is a general paucity of recognizable organic remains but occasional diatoms (*Coscinodiscus*), rotaline Foraminifera, sphaeroid Radiolaria and sponge spicules are seen.

Station **WS 598**. 19. v. 31. Lat. 35° 43′ S. Long. 73° 32′ W. 2307 m. (Plate XXII.)

Diatomaceous mud. This is a green mud formed of flocculent material enclosing small quartz grains which are generally less than 0·05 mm. in diameter. The organic debris is granular in appearance and contains cells of green algae and diatoms, among which frustules of *Coscinodiscus*, *Rhizosolenia* and *Chaetoceros* are noted.

Station **WS 599**. 19. v. 31. Lat. 35° 41′ 30″ S. Long. 73° 43′ W. 3265 m. (Plate XXII.)

DIATOMACEOUS MUD. This is essentially similar in general constitution to the preceding sample. Some fragments of green hornblende are noted among the more abundant quartz grains. The diatoms include frustules of *Coscinodiscus* and *Chaetoceros*.

Station **WS 602**. 28. v. 31. Lat. 32° 04′ 45″ S. Long. 71° 34′ W. 75 m. (Plate XXII.)

SHELLY SAND. This sample consists largely of calcareous material which includes the brachiopod *Magellania flavescens* (one entire shell), echinid spines, sponge spicules, fragments of gastropod shells, Polyzoa, pteropods and Foraminifera. Mineral grains, chiefly angular fragments of quartz, reach a diameter of 0·25 mm. Crystals of phillipsite (0·1 mm.) are plentiful among the finer material.

Station **WS 604**. 28. v. 31. Lat. 32° 05′ S. Long. 71° 45′ 30″ W. 687 m. (Plate XXII.)

TERRIGENOUS MUD. A dark green mud, formed mainly of angular mineral grains of which a large proportion are about 0·1 mm. in diameter. The minerals include quartz, white mica, green hornblende (some fibrous), staurolite (?) and volcanic glass. There is a small proportion of flocculent material which appears to be organic debris though no recognizable remains are noted.

Station **WS 605**. 28. v. 31. Lat. 32° 05′ S. Long. 71° 50′ W. 1296 m. (Plate XXII.)

TERRIGENOUS MUD. A brownish mud, consisting mainly of mineral grains, but with some flocculent matter. The great majority of the grains are less than 0·1 mm. in diameter. The larger grains include angular fragments of quartz (0·25 mm.), prismatic grains of green and brown hornblende (0·1 mm.), flakes of white mica (0·2 mm.) showing strain shadows, grains of staurolite and volcanic glass. Rotaline and textularian Foraminifera, together with sponge spicules are sparsely distributed through the deposit.

Station **WS 610**. 30. v. 31. Lat. 31° 45′ 30″ S. Long. 72° 01′ 30″ W. 2500 m. (approx.). (Plate XXII.)

DIATOMACEOUS MUD. This is a light brown mud in which the mineral constituent is subordinate in proportion to the flocculent material. The latter is of the usual indefinite character, but it includes frustules of *Coscinodiscus* together with occasional fragments of Radiolaria, milioline Foraminifera and sponge spicules. The mineral grains are mostly below 0·05 mm. in diameter, and include fragments of quartz and green hornblende besides splinters of volcanic glass.

Station **WS 616**. 5. vi. 31. Lat. 27° 08′ S. Long. 71° 10′ W. 1768 m. (Plate XXII.)

TERRIGENOUS MUD. This deposit has a large proportion of terrigenous material. Subangular grains of quartz up to 0·2 mm. in diameter are preponderant while prismatic grains of brown and green hornblende up to 0·15 mm. in length are often seen. The granular flocculent material encloses minute mineral grains and has a greenish hue. Sponge spicules are plentiful, and occasional rotaline Foraminifera, diatoms (*Coscinodiscus*) and filaments of green algae are noted.

Station **WS 617**. 5. vi. 31. Lat. 27° 09′ 30″ S. Long. 71° 15′ 42″ W. 3031 m. (Plate XXII.)

TERRIGENOUS MUD. Of similar constitution to the deposit from St. WS 616. Detrital grains include angular fragments of quartz (0·25 mm.), prismatic green hornblende, flakes of white mica, and splinters of volcanic glass. A few Radiolaria, sponge spicules, diatoms (*Coscinodiscus*) and rotaline Foraminifera occur, but not in sufficient quantity to give character to the deposit.

Station **WS 619**. 6. vi. 31. Lat. 27° 03′ 30″ S. Long. 71° 30′ W. 4864 m. (Plate XXII.)

TERRIGENOUS MUD. A black fetid mud which has oxidized to a brown colour round the margin of the sample. The black colour appears to be due to dense flocculent aggregates of exceedingly small particles whose precise nature is uncertain. These aggregates enclose a quantity of small, angular mineral grains. The bulk of the sample, however, consists of sand grains, the largest of which are about 0·15 mm. in diameter. The condition of the minerals varies from well-rounded grains to sharp, angular chips; quartz, brown and white mica, and green hornblende are noted. Apart from abundant sponge spicules, recognizable organisms are rare, comprising only occasional diatoms and fragments of Radiolaria.

Station **WS 622**. 8. vi. 31. Lat. 23° 32′ 36″ S. Long. 70° 38′ 30″ W. 148 m. (Plate XXII.)

DIATOMACEOUS MUD. An evil-smelling dark green mud, consisting, in the main, of granular flocculent material which is distinctly green in colour. Many of the denser granules have the appearance of unicellular algae, and brown spherical resting spores are present. Embedded in this material are sponge spicules and grains of quartz and green hornblende, the mineral particles grading downwards in size from a diameter of about 0·1 mm. to exceedingly small dimensions. There are a few Radiolaria and rotaline Foraminifera, while large frustules of *Coscinodiscus* are fairly numerous.

Station **WS 623**. 8. vi. 31. Lat. 23° 32′ 42″ S. Long. 70° 41′ W. 289 m. (Plate XXII.)

COARSE SAND. This is a coarse sand of speckled appearance. The mineral grains are fairly rounded, and reach a diameter of about 2 mm., while an angular pebble 2 cm. across is included in the sample. The latter is a tuff containing fragments of felspar and green hornblende. The sand grains also include opaque fragments and some quartz grains. Foraminiferal tests are plentiful, including textularian, cristellarian and rotaline forms.

Station **WS 638**. 19. vi. 31. Lat. 18° 54′ 30″ S. Long. 71° 06′ W. 2277 m. (Plate XXII.)

DIATOMACEOUS MUD. A black film has formed on the surface of the sample during storage. The deposit is largely a dense mass of greenish flocculent aggregates which contains occasional angular grains of quartz (0·1 mm.), green and brown hornblende and volcanic glass. Diatoms are not very plentiful but some undamaged frustules of *Coscinodiscus* are noted, together with sponge spicules.

Station **WS 639**. 19. vi. 31. Lat. 18° 44′ S. Long. 70° 48′ W. 1485 m. (Plate XXII.)

TERRIGENOUS MUD. A greenish brown mud, formed mainly of terrigenous material. The mineral grains include angular fragments of quartz (0·15 mm.), green hornblende (0·1 mm.) and volcanic glass (0·1 mm.). There is some quantity of granular flocculent matter, sometimes in dense aggregates, which enclose tiny, angular mineral grains. Recognizable organic remains are scarce, though frustules of *Coscinodiscus* and *Entopyla* are present.

Station **WS 640**. 19. vi. 31. Lat. 18° 28′ S. Long. 70° 23′ 36″ W. 82 m. (Plate XXII.)

DIATOMACEOUS MUD. This greenish mud contains a considerable proportion of detrital material, including angular grains of quartz (up to 0·2 mm. diameter), green hornblende (0·15 mm.), brown hornblende (0·1 mm.) and volcanic glass (0·2 mm.). Frustules of *Coscinodiscus* are conspicuous by their size (up to 0·3 mm.); other genera include *Actinoptychus*, *Amphora*, *Cocconeis* and *Navicula*. The green flocculent material includes broken diatom frustules and minute mineral grains.

Station **WS 641**. 19. vi. 31. Lat. 18° 27′ 30″ S. Long. 70° 26′ 30″ W. 105 m. (Plate XXII.)

DIATOMACEOUS MUD. This is a green mud very similar to the preceding sample. The terrigenous material includes angular grains of quartz and green hornblende, up to about 0·2 mm. in diameter. There is a fair proportion of flocculent matter, often in dense aggregates enclosing small mineral grains. *Coscinodiscus* again is conspicuous by the size of the frustules, and other diatoms include *Navicula*, *Fragilaria*, *Actinoptychus* and *Amphora*.

Station **WS 642**. 19. vi. 31. Lat. 18° 28′ 24″ S. Long. 70° 32′ 12″ W. 148 m. (Plate XXII.)

DIATOMACEOUS MUD. A dark green mud composed mainly of dense, green, flocculent aggregates, which are granular in appearance. This material contains brown resting spores and plentiful diatoms of the genera *Coscinodiscus*, *Actinoptychus*, *Thalassiothrix* and *Fragilaria*. One example of *Bacteriastrum* is seen to contain brown resting spores similar to, but smaller than, the loose spores in the flocculent material. The mineral constituent consists mainly of angular grains of quartz and volcanic glass, embedded in the flocculent "matrix".

Station **WS 647**. 22. vi. 31. Lat. 15° 19′ 12″ S. Long. 75° 11′ 30″ W. 65 m. (Plate XXII.)

FINE SAND. The sample consists almost entirely of detrital mineral grains, but there is a small amount of flocculent material which, however, is sufficient to impart a greenish tinge to the sand. The grains are mainly angular and include quartz (0·25 mm.), plagioclase felspar (0·2 mm.), green hornblende (0·1 mm.) and volcanic glass (0·2 mm.). Among diatoms, large frustules of *Coscinodiscus* are abundant and some contain brown resting spores. *Actinoptychus* commonly occurs, while *Navicula*, *Synedra*, *Grammotophora*, *Achnanthes*, *Pleurosigma* and *Entopyla* are less numerous. Sponge spicules and Foraminifera (cristellarians and textularians) are also present in the deposit.

Station **WS 648**. 22. vi. 31. Lat. 15° 19′ 30″ S. Long. 75° 13′ W. 111 m. (Plate XXII.)

DIATOMACEOUS MUD. A green mud, consisting mainly of flocculent diatomaceous material with only a small proportion of detrital mineral grains. The latter are chiefly angular grains of quartz and green hornblende which do not average more than 0·05 mm. in diameter. Though diatoms are plentiful, the variety of forms is not great. The largest and most abundant frustules are those of *Coscinodiscus*, many of which reach a diameter of nearly 0·5 mm.; some have greenish cell contents, others contain brown resting spores. Other forms which are occasionally seen are *Actinoptychus*, *Achnanthes* and *Grammatophora*. Brown resting spores also occur loose in the green flocculent material.

Station **WS 649**. 22. vi. 31. Lat. 15° 20′ S. Long. 75° 16′ 30″ W. 137 m. (Plate XXII.)

DIATOMACEOUS MUD. This sample differs from the preceding chiefly in the greater maximum size of the sand grains; in the present sample some angular quartz grains are 0·2 mm. across, and prisms of green hornblende are nearly as long. But the mineral constituent is relatively smaller in amount than the flocculent matter which is closely similar to that from St. WS 648. There is also the same preponderance of large frustules of *Coscinodiscus*, and the associated diatoms include *Actinoptychus*, *Achnanthes* and *Navicula*.

Station **WS 650**. 22. vi. 31. Lat. 15° 22′ 30″ S. Long. 75° 22′ W. 143 m. (Plate XXII.)

COARSE SAND. The major fraction consists of colourless and opaque sand grains, more or less rounded in shape, up to 2 mm. in diameter. They are often coated with green flocculent matter. In the finer material a large species of *Coscinodiscus* commonly occurs with textularian and rotaline Foraminifera. The granular flocculent material also encloses abundant crystals of phillipsite.

Station **WS 651**. 22. vi. 31. Lat. 15° 31′ S. Long. 75° 37′ 30″ W. 1264 m. (Plate XXII.)

DIATOMACEOUS MUD. This deposit is composed mainly of green flocculent matter in which broken tests of diatoms, and brown resting spores are abundant. A large species of *Coscinodiscus* occurs plentifully, while frustules of *Entopyla*, *Achnanthes* and *Actinoptychus* are less numerous. Some of the frustules enclose brown resting spores. The sand grains embedded in the flocculent mass are mostly less than 0·05 m. in diameter, though some reach 0·1 mm. Angular grains of quartz and prismatic grains of green hornblende represent the chief minerals.

Station **WS 652**. 23. vi. 31. Lat. 16° 21′ 30″ S. Long. 76° 30′ 12″ W. 3840 m. (Plate XXII.)

DIATOMACEOUS MUD. An unctuous grey-brown mud composed almost entirely of flocculent matter, in which diatom frustules occur in all stages of disintegration. *Coscinodiscus* is represented in abundance by unbroken frustules, and Radiolaria are present in small numbers. The minor proportion of mineral grains includes quartz and green hornblende in fragments which are usually less than 0·05 mm. in diameter.

Station **WS 655**. 24. vi. 31. Lat. 16° 08′ S. Long. 76° 22′ W. 3315 m. (Plate XXII.)

DIATOMACEOUS MUD. This brown mud is so similar to the preceding that the same description applies.

Station **WS 658**. 25. vi. 31. Lat. 13° 45′ 30″ S. Long. 76° 20′ W. 16 m. (Plate XXII.)

DIATOMACEOUS MUD. A dark green, rather sandy, mud of which the greater proportion consists of mineral grains, mostly angular in form and ranging from a diameter of about 0·25 mm. to exceedingly small dimensions. Quartz, volcanic glass and green hornblende are the chief constituents. The flocculent material contains diatoms, among which *Coscinodiscus* is large and abundant, *Actinoptychus* of common occurrence, while navicular forms are less plentiful.

Station **WS 663**. 1. vii. 31. Lat. 12° 09′ 36″ S. Long. 77° 15′ W. 62 m. (Plate XXII.)
DIATOMACEOUS MUD. A dark green mud of similar constitution to the preceding. The minerals are represented by quartz, felspar, green hornblende and volcanic glass in angular grains up to 0·2 mm. in diameter. There is a fair amount of flocculent material containing diatom frustules and brown resting spores. The diatoms noted are *Coscinodiscus* (abundant), *Chaetoceros*, *Navicula*.

Station **WS 664**. 1. vii. 31. Lat. 12° 11′ 30″ S. Long. 77° 17′ W. 100 m. (Plate XXII.)
DIATOMACEOUS MUD. This green mud differs from the last two samples in the greater proportion of flocculent material. The presence of fragments of algal thalli containing resting spores and other cell contents leaves little doubt as to the nature of the flocculent aggregates. *Coscinodiscus* and *Actinoptychus* are the principal diatoms; the former is particularly large and abundant, and many frustules contain brown resting spores. Mineral grains, including quartz and green hornblende, are mostly angular in shape, and occur up to 0·2 mm. in diameter.

Station **WS 665**. 1. vii. 31. Lat. 12° 13′ 18″ S. Long. 77° 21′ 48″ W. 132 m. (Plate XXII.)
DIATOMACEOUS MUD. The coarser fraction of this dark green mud consists of detrital material grains with a maximum diameter of about 0·3 mm.; the average size, however, is much less. Angular fragments of quartz, green hornblende, felspar and volcanic glass are noted. There is a considerable amount of green flocculent material which includes pieces of algal thalli and diatoms, among which *Coscinodiscus*, *Actinoptychus*, *Navicula* and *Triceratium* are prominent; some frustules contain brown resting spores. Occasional textularian and rotaline Foraminifera, a radiolarian test and the silicoflagellate *Dictyocha fibula* are noted.

Station **WS 666**. 1. vii. 31. Lat. 12° 18′ 30″ S. Long. 77° 30′ 30″ W. 198 m. (Plate XXII.)
DIATOMACEOUS MUD. Dark green mud of which flocculent matter is the chief constituent. This green and granular aggregate contains frustules of *Coscinodiscus*, *Actinoptychus*, *Cocconeis* and *Amphora*, together with a small proportion of mineral grains. The latter are mainly angular fragments of quartz, green hornblende and volcanic glass, the size of which is less than a maximum of 0·2 mm. in diameter.

Station **WS 667**. 1. vii. 31. Lat. 12° 23′ 12″ S. Long. 77° 39′ 30″ W. 474 m. (Plate XXII.)
SAND AND GRAVEL. This sample consists of a few angular, black pebbles up to 5 mm. across, and a small quantity of sand. The sand grains are mainly angular fragments of dark brown volcanic glass (0·2 mm.), some shell fragments and a few grains of green hornblende. There are also some colourless radial aggregates of a zeolite mineral, probably phillipsite, some of which reach a diameter of about 0·2 mm.

Station **WS 669**. 2. vii. 31. Lat. 12° 33′ 30″ S. Long. 78° 21′ 36″ W. 3840 m. (Plate XXII.)
DIATOMACEOUS MUD. This sample consists mainly of the usual flocculent aggregates with diatoms and sand grains. Whole frustules of *Coscinodiscus* are abundant, and many contain resting spores. The silicoflagellate *Dictyocha fibula* is noted as of occasional occurrence. Mineral grains are generally angular and of small size, but occasional grains of quartz, green hornblende and volcanic glass reach a diameter of about 0·2 mm.

Station **WS 671**. 3. vii. 31. Lat. 12° 10′ 48″ S. Long. 77° 59′ 12″ W. 1934 m. (Plate XXII.)
DIATOMACEOUS MUD. The main constituent is granular flocculent material containing brown resting spores and diatoms. The most prominent genera are *Coscinodiscus* (large and abundant), *Triceratium*, *Actinoptychus*, *Synedra* and *Navicula*. Occasional Radiolaria (*Eucyrtidium* and *Lithostrobus*) and the silicoflagellate *Dictyocha fibula* are noted. Mineral grains, sparsely distributed in the deposit, include quartz, green hornblende and volcanic glass, in grains up to 0·1 mm. in diameter.

Station **WS 676**. 10. vii. 31. Lat. 08° 17′ S. Long. 79° 01′ 30″ W. 29 m. (Plate XXII.)

DIATOMACEOUS MUD. A black mud in which the flocculent aggregates are in excess of the mineral constituent. The former contain resting spores and diatom debris, besides whole frustules of *Coscinodiscus* (large and abundant), *Actinoptychus* and *Navicula*. The spores and the flocculent matter are almost black, especially the denser portions of the latter, a feature which is presumably due to local peculiarities of decomposition. Textularian Foraminifera and fragments of Radiolaria also occur. Most of the mineral grains are extremely small, but some range up to a diameter of about 0·1 mm.; they include angular grains of quartz and volcanic glass.

Station **WS 677**. 10. vii. 31. Lat. 08° 19′ 30″ S. Long. 79° 05′ 45″ W. 45 m. (Plate XXII.)

DIATOMACEOUS MUD. The general constitution of this deposit is very similar to that last described, but the flocculent matter is green and the spores remain brown. Among diatoms, *Coscinodiscus* is large and abundant, *Actinoptychus* and *Navicula* are less plentiful. Textularian and rotaline Foraminifera are of frequent occurrence. Mineral grains, present in subordinate quantity, are mostly very small, but quartz grains up to 0·1 mm. and splinters of volcanic glass up to 0·2 mm. are noted.

Station **WS 678**. 10. vii. 31. Lat. 08° 35′ 30″ S. Long. 78° 57′ W. 54 m. (Plate XXII.)

DIATOMACEOUS MUD. This sample presents no essential difference from the last, though some of the quartz grains attain a greater size, namely, about 0·25 mm. in diameter. Otherwise there is the same excess of flocculent matter over the mineral constituents and the same assemblage of diatoms.

Station **WS 680**. 10. vii. 31. Lat. 08° 44′ S. Long. 79° 15′ W. 91 m. (Plate XXII.)

FINE SAND. A green sandy deposit with many mineral grains of about 0·25 mm. in diameter. They include angular grains of quartz (up to 0·4 mm. diameter), prismatic grains of green hornblende (0·25 mm. long), brown hornblende of the same habit and size, and splinters of volcanic glass (0·1 mm. across). The larger grains are in excess of the finer material. There is a small amount of green, granular, flocculent matter which gives colour to the sand and the liquid. Resting spores and fragments of *Coscinodiscus* are the only organic remains recognized.

Station **WS 686**. 17. vii. 31. Lat. 09° 25′ 30″ S. Long. 80° 22′ W. 4206 m. (Plate XXII.)

DIATOMACEOUS MUD. A grey-green mud in which the flocculent material is in excess compared with the mineral constituent. The mineral grains include quartz (about 0·05 mm. diameter), green hornblende (prismatic grains up to 0·1 mm. in length) and splinters of volcanic glass. The principal diatoms in the flocculent material are *Coscinodiscus*, *Actinoptychus* and *Achnanthes*.

Station **WS 689**. 18. vii. 31. Lat. 07° 01′ S. Long. 81° 09′ W. 2093 m. (Plate XXII.)

DIATOMACEOUS MUD. A green mud very similar to the last, but with perhaps a larger proportion of mineral grains which include quartz (0·1 mm.), green hornblende (0·1 mm.) and volcanic glass (0·05 mm.). The flocculent material is largely diatomaceous in character; it contains whole frustules of *Coscinodiscus* (large and abundant) together with small rotaline Foraminifera.

Station **WS 692**. 19. vii. 31. Lat. 06° 29′ 15″ S. Long. 80° 33′ W. 25 m. (Plate XXII.)

MEDIUM SAND. The sample is a small quantity of sand with shell fragments. The minerals include quartz in angular grains up to 0·4 mm. in diameter, flakes of white mica 0·5 mm. across, and opaque grains with about the same diameter. Large frustules of *Coscinodiscus* are present.

Station **WS 694**. 19. vii. 31. Lat. 06° 38′ S. Long. 80° 49′ 54″ W. 1216 m. (Plate XXII.)

DIATOMACEOUS MUD. The green flocculent material contains brown resting spores and diatom debris, among which many whole frustules of *Coscinodiscus*, *Actinoptychus*, *Synedra* and *Achnanthes* are noted. The mineral grains are usually very small, but some angular grains of quartz, brown hornblende and volcanic glass reach a diameter of about 0·1 mm.

Station **WS 696**. 20. vii. 31. Lat. 06° 54′ 48″ S. Long. 81° 02′ W. 1901 m. (Plate XXII.)

DIATOMACEOUS MUD. This deposit has the same general characters as the foregoing sample. The flocculent material is in excess over the mineral constituent and contains whole frustules of *Coscinodiscus*, *Triceratium* and *Navicula*, the first named being most numerous. The silicoflagellate *Dictyocha* *fibula* is occasionally seen. The mineral grains include quartz (up to 0·15 mm. diameter) and green hornblende (0·05 mm. diameter).

Station **WS 697**. 21. vii. 31. Lat. 05° 55′ 30″ S. Long. 81° 09′ W. 75 m. (Plate XXII.)

DIATOMACEOUS MUD. A dark sandy mud in which mineral grains form a greater bulk than flocculent matter. The mineral grains are mostly angular fragments of quartz, brown and green hornblende, volcanic glass, with a maximum diameter of about 0·2 mm., but flakes of white mica are sometimes 0·5 mm. across; a small crystal of tourmaline (0·05 mm.) is also noted. The flocculent material is present in considerable quantity, and whole frustules of *Coscinodiscus*, *Biddulphia*, *Actinoptychus* and *Navicula* are plentiful. A few tests of the silicoflagellate *Dictyocha fibula* are noted.

Station **WS 700**. 21. vii. 31. Lat. 05° 52′ S. Long. 81° 15′ 30″ W. 310 m. (Plate XXII.)

DIATOMACEOUS MUD. The sample consists mainly of green, granular, flocculent material which contains entire frustules of *Coscinodiscus*, *Actinoptychus*, *Achnanthes* and *Navicula*, the first-named being particularly large and abundant. The mineral fraction contains small angular grains of quartz, volcanic glass and brown hornblende, which are mostly less than 0·05 mm. in diameter.

Station **WS 701**. 21. vii. 31. Lat. 05° 48′ S. Long. 81° 22′ 30″ W. 1083 m. (Plate XXII.)

DIATOMACEOUS MUD. This consists largely of flocculent material of the usual type, in which frustules of *Coscinodiscus* are prominent; the silicoflagellate *Dictyocha fibula* and textularian Foraminifera are occasionally seen. Mineral grains, usually below 0·05 mm. in diameter, are mainly of quartz and volcanic glass.

Station **WS 702**. 21. vii. 31. Lat. 05° 38′ S. Long. 81° 40′ W. 3102 m. (Plate XXII.)

DIATOMACEOUS MUD. Large frustules of *Coscinodiscus* are plentiful together with smaller tests of *Actinoptychus* and *Synedra* in the flocculent material which is of the usual type. In the small amount of mineral grains, quartz, volcanic glass and green hornblende occur in fragments which are usually less than 0·05 mm. in diameter.

Station **WS 703**. 22. vii. 31. Lat. 05° 34′ S. Long. 81° 11′ 30″ W. 4742 m. (Plate XXII.)

DIATOMACEOUS MUD. The deposit is composed largely of granular flocculent material in which large frustules of *Coscinodiscus* are plentifully distributed. Apart from this, recognizable diatoms are not numerous but the occurrence of *Asteromphalus* is noted. Angular quartz grains (0·05 mm.) are sparsely scattered through the flocculent mass.

Station **WS 705**. 23. vii. 31. Lat. 05° 35′ 30″ S. Long. 83° 41′ 45″ W. 4026 m. (Plate XXII.)

DIATOMACEOUS MUD. An unctuous brown mud with a small proportion of tiny mineral grains (less than 0·01 mm. diameter), chiefly angular particles of quartz and volcanic glass. The flocculent aggregates enclose abundant frustules of *Coscinodiscus* together with some of *Synedra* and *Thalassiothrix*, also fragments of Radiolaria.

Station **WS 708**. 25. vii. 31. Lat. 04° 18′ S. Long. 82° 05′ W. 4314 m. (Plate XXII).

DIATOMACEOUS MUD. Composed of green flocculent material of the usual type with a very small amount of mineral grains, mostly less than 0·01 mm. in diameter. *Coscinodiscus* is the most prominent of the diatoms and there are numerous fragments of Radiolaria.

Station **WS 711**. 27. vii. 31. Lat. 04° 19′ 30″ S. Long. 81° 27′ W. 1885 m. (Plate XXII.)

TERRIGENOUS MUD. This sample is formed largely of flocculent material which is responsible for the green colour of the deposit. A few diatoms (*Coscinodiscus*) are present, usually retaining their cell contents. The flocculent matter is more abundant than usual in a typical terrigenous deposit, but there is a general paucity of recognizable organisms. The mineral grains are mainly subangular in shape and include quartz (up to 0·25 mm.) and green hornblende.

Station **WS 717**. 31. vii. 31. Lat. 02° 02′ S. Long. 81° 18′ 30″ W. 1649 m. (Plate XXII.)

DIATOMACEOUS MUD. This sample has a fair proportion of sandy material, the grains of which are mainly about 0·1 mm. in diameter. The quartz grains reach a maximum of 0·25 mm., while fragments of green hornblende are usually much smaller (0·05 mm.). The flocculent material forms dense green aggregates which impart their colour to the deposit; it contains entire frustules of *Coscinodiscus* and occasional fragments of Radiolaria.

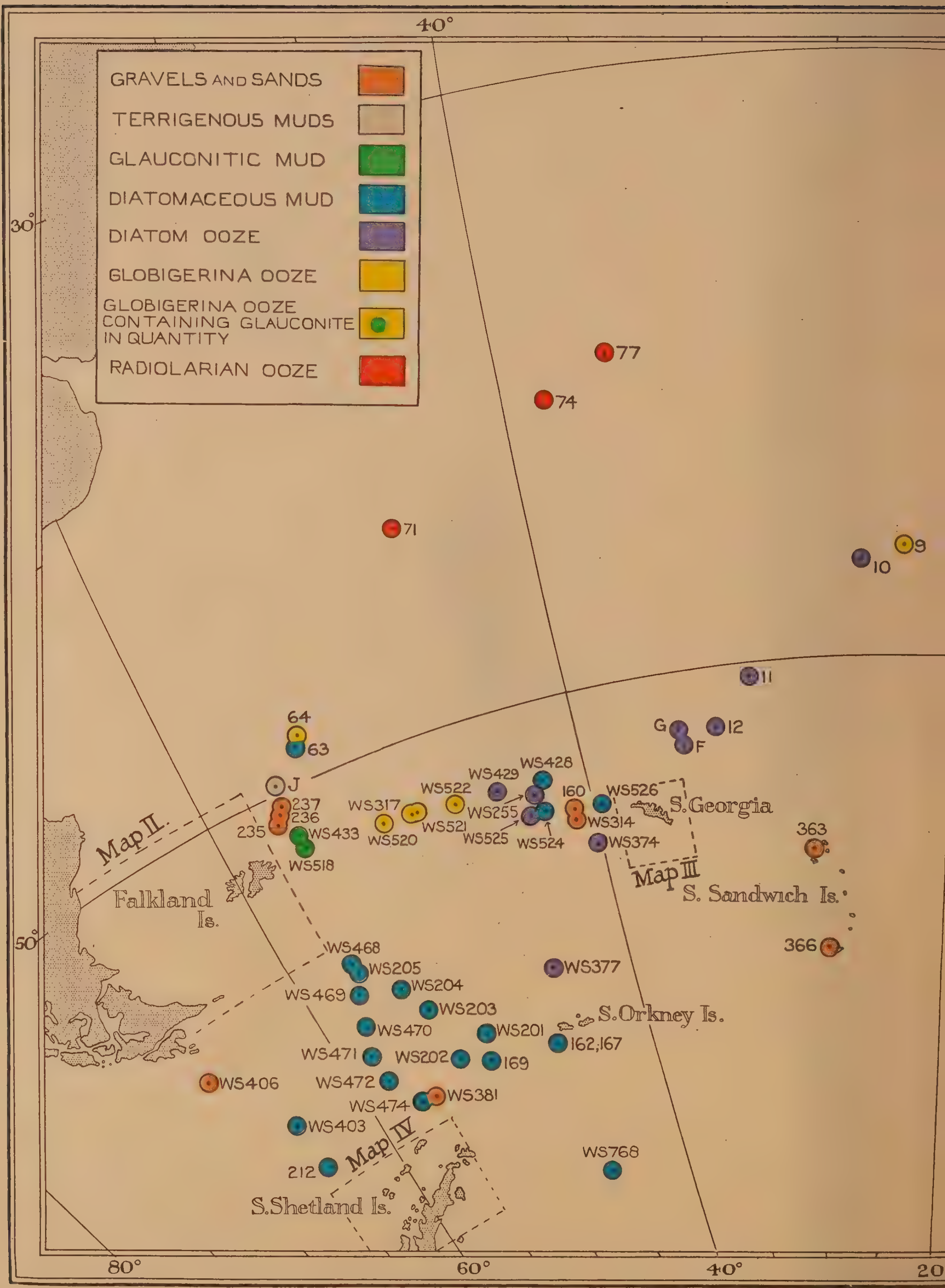
Station **WS 768**. 20. x. 31. Lat. 45° 31′ S. Long. 63° 23′ W. 108 m. (Plate XVII.)

DIATOMACEOUS MUD. The deposit contains a considerable proportion of mineral grains. Some subangular and rounded quartz grains reach 0·5 mm. in diameter, while prismatic grains of green hornblende and brown volcanic glass are 0·2 mm. in length. The worn appearance of these larger grains is in contrast with the fresh and angular quality of many grains between 0·1 and 0·01 mm. in diameter. Though flocculent material forms a conspicuous proportion of the deposit, recognizable diatoms are not very plentiful; they include *Thalassiosira*, *Coscinodiscus*, *Pleurosigma*, and a chain form which is not identified. A few foraminiferal tests are present.

MARINE BIOLOGICAL STATION

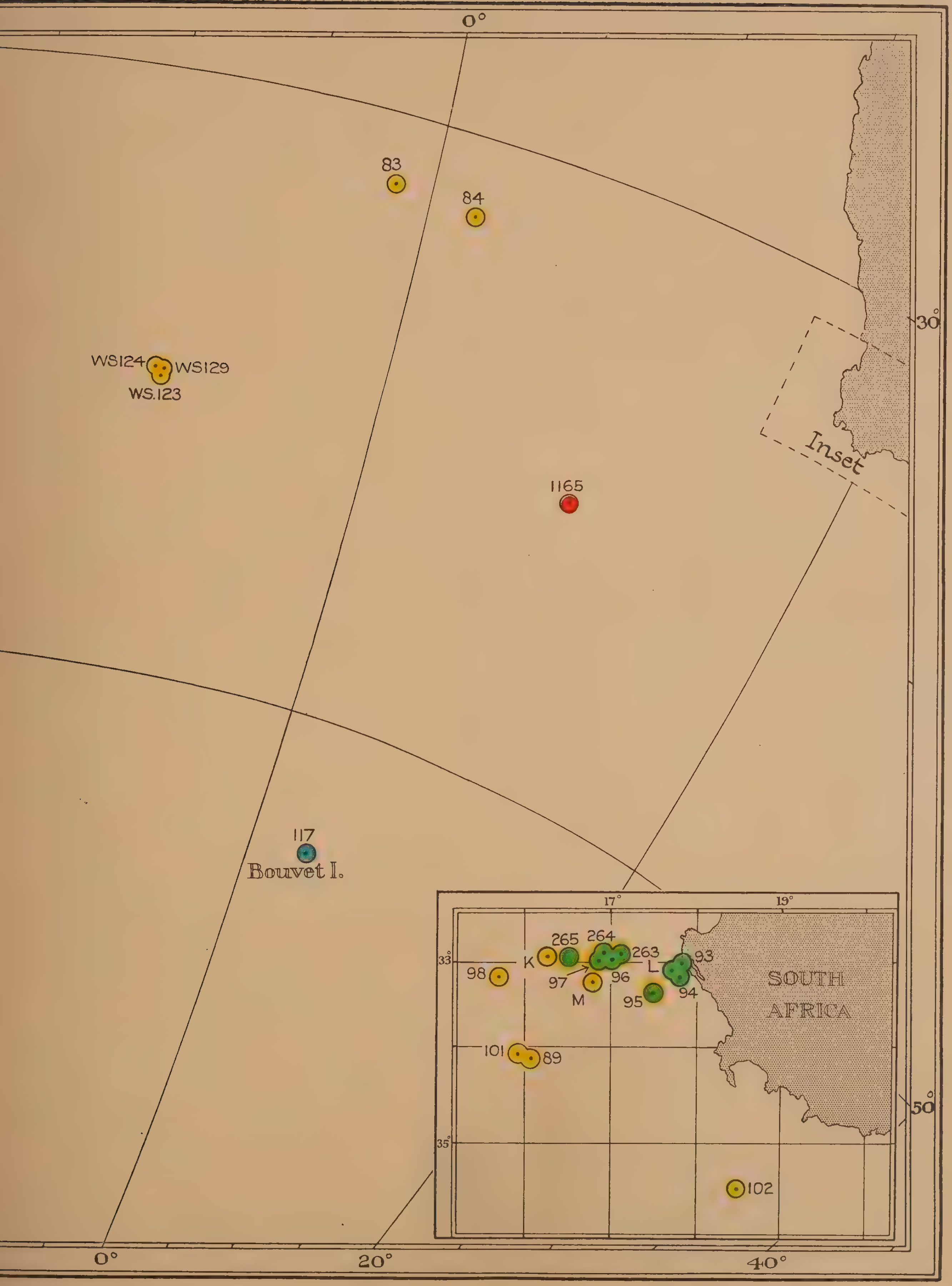
Station **MS 68**. 2. iii. 25. East Cumberland Bay, South Georgia; 1·7 miles S $\frac{1}{2}$° E to 8$\frac{1}{2}$ cables south-east by east of Sappho Point. 220–247 m.

DIATOMACEOUS MUD. A fine-grained deposit, mainly debris of diatom tests, but some entire centric diatoms. The mineral grains are extremely small, though some of the larger detrital grains are more than 0·1 mm. in diameter.



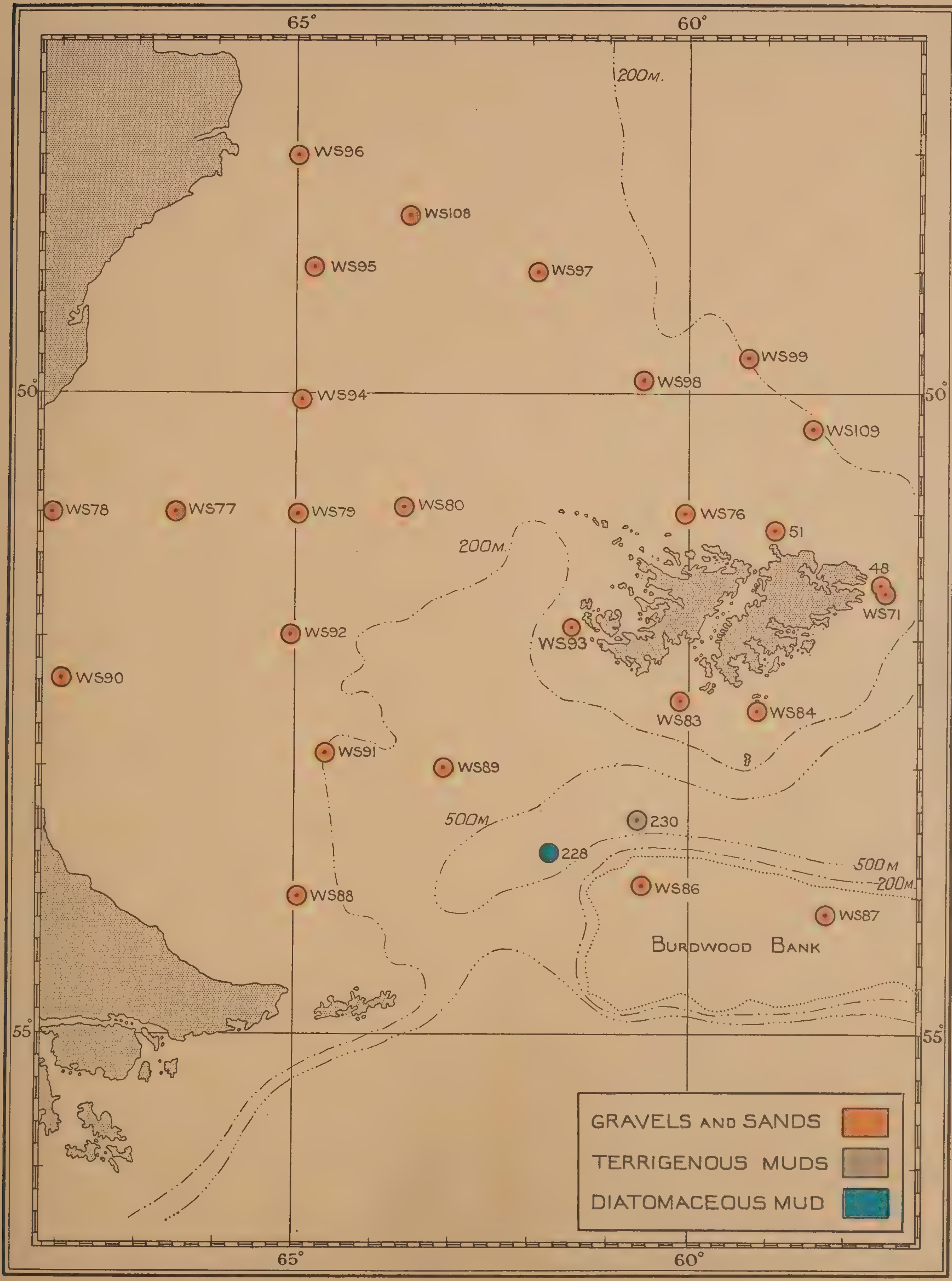
SOUTH ATLANTI

PLATE XVII

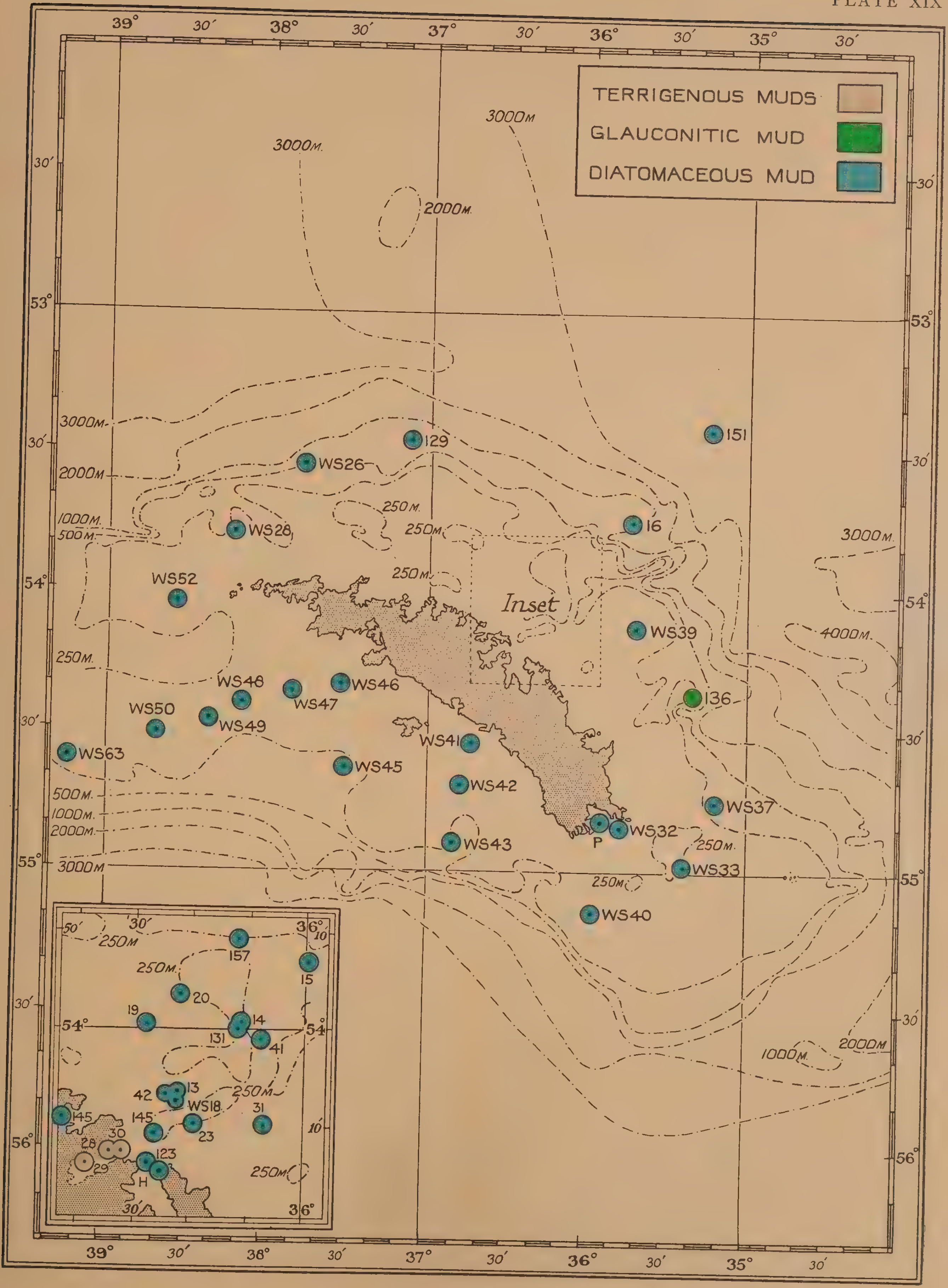


OUTHERN OCEANS

PLATE XVIII

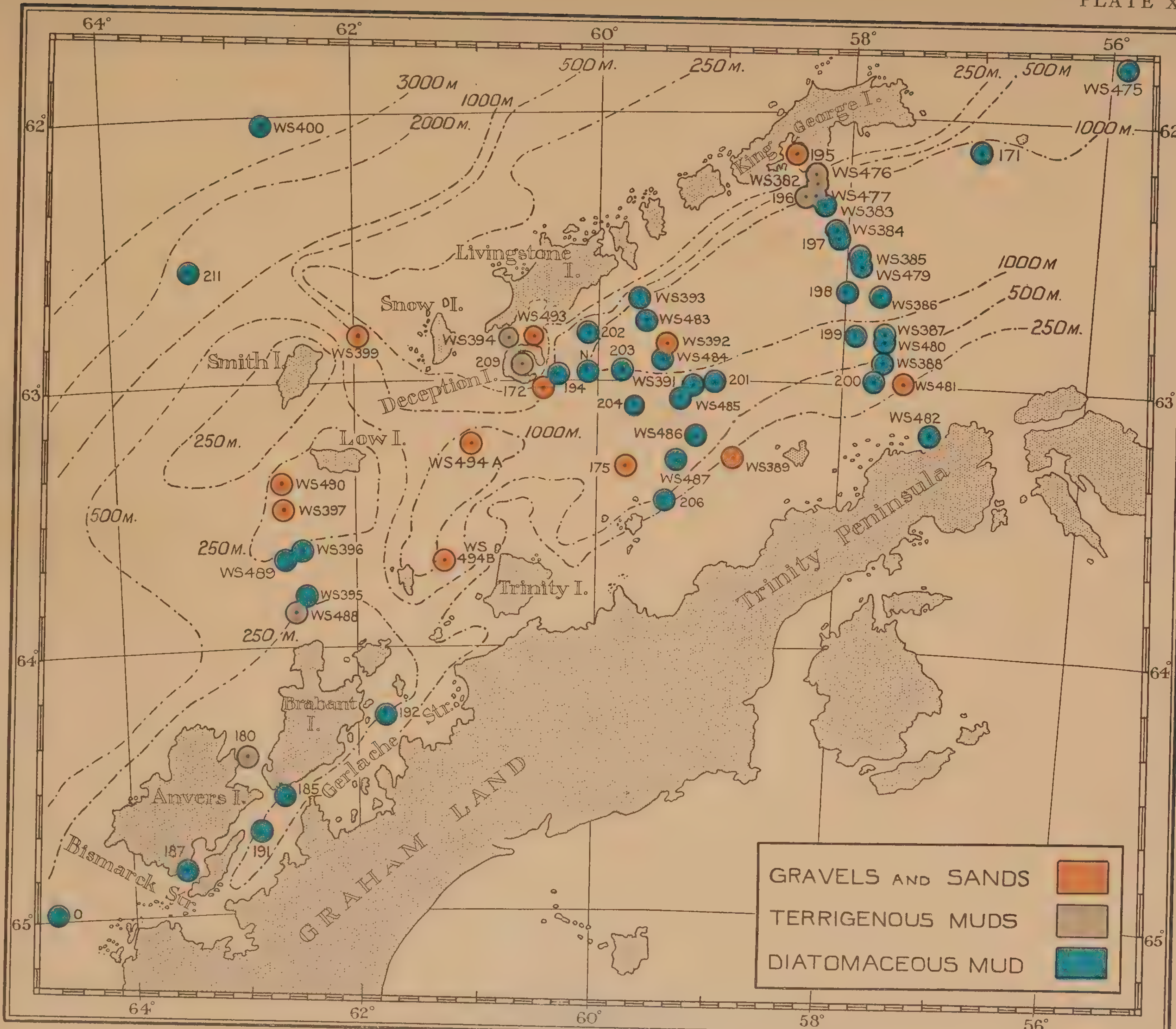


FALKLAND ISLANDS



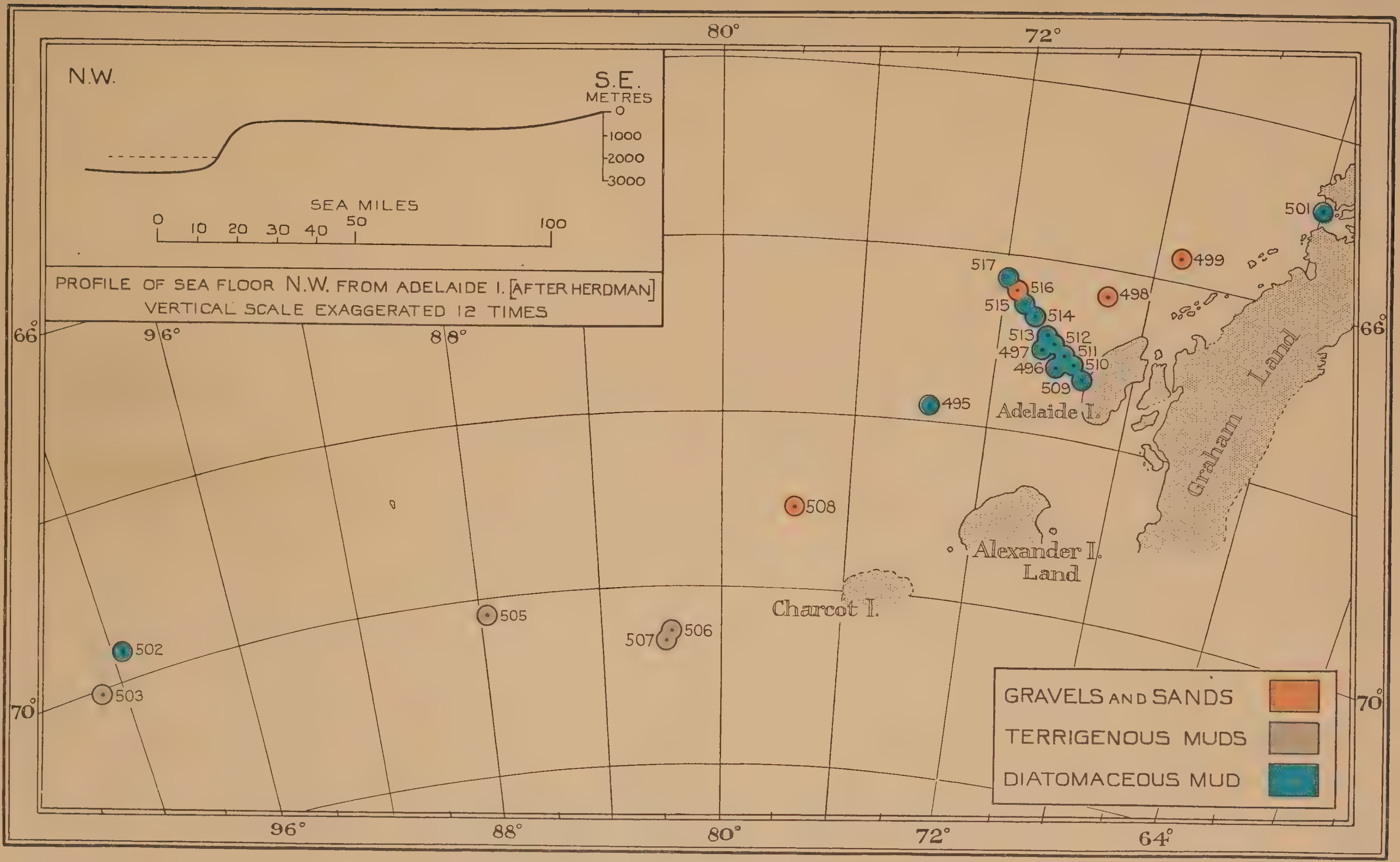
SOUTH GEORGIA

PLATE XX

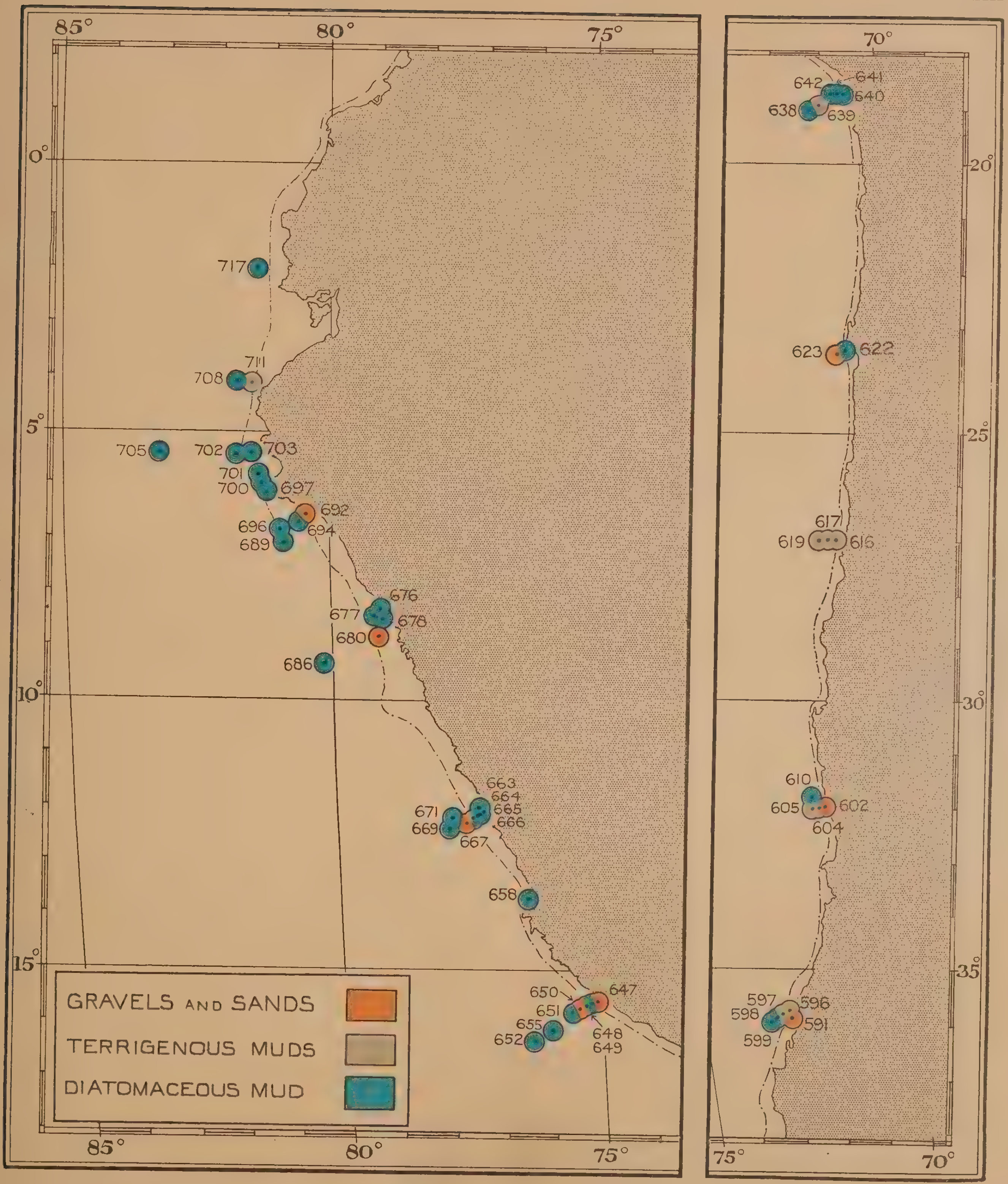


SOUTH SHETLAND ISLANDS AND PALMER ARCHIPELAGO

PLATE XXI



BELLINGHAUSEN SEA



WEST COAST OF SOUTH AMERICA

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INVESTIGATIONS

ON THE STOCK OF WHALES AT SOUTH GEORGIA

By

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ON THE STOCK OF WHALES AT SOUTH GEORGIA

By J. F. G. Wheeler, D.Sc.

(Text-figs. 1–3)

The application of the method of age determination described in a previous paper has brought into prominence the complex nature of the whale population which year after year since 1904 has been attacked by the catchers of the companies operating from South Georgia. Study of the age composition of the population strongly suggests reduction of the stock, and some advance has been made towards ascertaining the rate at which reduction has proceeded. Work on these lines, when considered in relation to other investigations, such as the movements of stock, affords a fair prospect of reaching, in this area at least, a scientific basis for the attainment and maintenance of economic security.

Several points of interest arose as the results of age determinations were studied. The calculated rate of reduction is not without interest and suggestiveness. Wholly dependent as it is upon the unit character of the recurring whale population and carrying within itself evidence that sections, at least, of the population are not present in the area in their true proportion, it provokes consideration of the real nature of the catch and enquiry into the population from which the catch was drawn.

This paper is an attempt to give the steps by which the calculation of the rate of reduction was made possible and a brief review of the problems underlying the study of whale stocks.

The treatment of the data had of necessity to be undertaken from a statistical point of view and for this part of the work I am indebted to Mr T. Edser of the Ministry of Agriculture and Fisheries, whose expert advice has been invaluable, and to Mr G. E. R. Deacon of the Discovery staff. I am also grateful to Dr Stanley Kemp, and to Sir Sidney Harmer and Mr J. O. Borley of the Discovery Committee, for much constructive and willing assistance.

Since 1925 members of the scientific staff of the Discovery Committee have been engaged at South Georgia in an intensive enquiry into the biology of whales, during the course of which a large proportion of the whales brought in for commercial purposes by the Compañia Argentina de Pesca has been examined. Following out an indication of a method of age determination given on pp. 450–2 of *Southern Blue and Fin Whales* (Mackintosh and Wheeler, 1929), a definite correlation was established in season 1929–30 between the number of corpora lutea in the ovaries of female Fin whales and physical maturity as indicated by the ankylosis of the vertebral epiphyses to their centra, and further light was thrown on the theory that age can be determined in the females of this species from the number of corpora lutea. These results were put forward in a later paper (Wheeler, 1930), in which it is shown that physical maturity is correlated with the presence of fifteen corpora lutea in the ovaries and reasons are given for considering that females with from one to four corpora lutea are in their first or second year from sexual maturity; those with from five to nine corpora lutea are in their third or fourth year from sexual maturity; those with from ten to fourteen are in their fifth or sixth year, and so on.

Such a method of estimation is, of course, applicable only to females. No way is yet known by which the age of the mature male whale can be determined. Also, as Blue whales have not figured in the catches to the same extent as Fins, our conclusions are confined to the latter species.

Observations made by the Discovery staff cover seven seasons during five of which almost the entire catch of the company was examined. Some months of fishing were unavoidably missed in each of the remaining seasons, and, as will be shown later, this is a matter of importance when assessing the representative nature of the catch.

The total number of female Fin whales recorded was 879, but of these 277 were shown to be sexually immature by examination of the internal genitalia, and 130 were so badly decomposed, or so badly damaged internally, that the genitalia could not be examined. An approximate division of this last group into sexually mature and immature can, of course, be made using length as criterion (Mackintosh and Wheeler, p. 417), and the figures then read 281 immature (32 per cent of the total) and 598 mature whales. In 472 of the latter full ovarian records are available.

The analysis of the 472 sexually mature whales into two-year groups commencing at sexual maturity and dependent upon the number of corpora lutea is as follows:

Table I

Female Fin whales

Number of corpora lutea	1–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49
Years from sexual maturity	1–2	3–4	5–6	7–8	9–10	11–12	13–14	15–16	17–18	19–20
1924–25	16	6	6	2	3	2	—	—	—	—
1925–26	19	26	15	7	4	3	1	1	—	—
1926–27	4	3	6	4	—	1	—	—	—	—
1927–28	1	2	1	1	1	—	—	—	—	—
1928–29	32	14	14	11	2	2	2	—	—	—
1929–30	52	42	21	24	24	16	6	2	1	1
1930–31	23	10	16	7	7	6	1	1	—	—
Totals ...	147	103	79	56	41	30	10	4	1	1

The taking of an annual unselected sample from an ageing stock to which annual additions are made at the lower age limit (which is, in effect, what the whaling companies have been doing) results inevitably in a heightening of the progressive diminution among the older members of the catch naturally caused by ordinary mortality. The figures given, although not impressively numerous, demonstrate this rapid diminution. If the catch of a single season were sufficiently large, or if examination could have been made of all the female Fin whales brought in to all the stations during a single season the sample would have been nearer the ideal. In the circumstances the figures for several seasons have been taken together and considered as a unit, although it is realized that changes may have occurred in the size of the stock and the intensity of fishing from season to season during the period of investigation to make the calculated rate of reduction only an approximation. It is, for instance, likely that the last two seasons were adversely affected by the pelagic fishery to the south and east of the island; and as in these seasons a greater percentage of the whales brought in was examined, the rate of reduction will be unduly weighted by them. The proportion of the catch we examined, however, was a random sample of the catch of the Pesca company, since, when whales were missed, no selection was made. Our sample should be therefore just as representative of the local population as the slightly larger Pesca catch. The over-weighting of the later seasons will certainly affect the rate of reduction if the stock is attacked elsewhere, but that is part of the disability of treating several seasons together, and if the damage has been done, then the calculated rate of reduction is more closely applicable to present day conditions than it would be if the earlier seasons alone were considered.

The missing of whales here and there during the season cannot affect the sample when no selection is made, but the absence of observations for a considerable part of the season is a different matter. Partial catches are not admissible in the analysis of age-group reduction since fluctuations are known to occur during the season not only between the numbers of each species present on the grounds but also between the numbers of each sex and stage of maturity of each species. Thus in *Southern Blue and Fin Whales* (p. 460) it is remarked that "when the first and second halves of a season at South Georgia are compared it is found that in the first half the catch is composed of a majority of mature whales, while in the second there is an influx of immature whales (and perhaps a withdrawal of adults) which causes a sharp reduction in the average lengths" and again "Apart from the fact that immature whales have occurred in relatively greater numbers in the latter part of the season, there is an indication that of the adult whales themselves, those taken early in the season are mostly older than those taken later". This is shown very clearly in Fig. 1 in which physical maturity has been used as a distinguishing character contrasted with early sexual maturity and sexual immaturity. Over five complete seasons the majority of physically mature females appeared in December, the majority of sexually mature not physically mature females in January and the peak of the influx of immatures was in February.

In seasons 1924–5 and 1927–8 observations were not commenced until well into the second half of the season, consequently the figures for these seasons must be neglected in the consideration of stock reduction since in both the proportion of the younger section of the population will be abnormal. The number of whales is now reduced by 41 to 431.

The division of the catch into age groups may now be examined. Following the attainment of sexual maturity whales are considered to give birth normally at recurrent intervals of two years. Each two-year period is occupied in gestation (eleven and a half months) and lactation (six months) after which is a resting period when the activity of the reproductive organs subsides until the onset of the next sexual season. Each age group should therefore consist of ovulating, pregnant, lactating and resting whales covering the two-year period. It should be capable, moreover, of further analysis into a one-year grouping, the lactating and resting whales being a year older than those ovulating or pregnant. At South Georgia, however, ovulating whales are rare and it has been shown that breeding is, in all likelihood, restricted to northern waters. Ovulation does occur exceptionally in the south but this does not necessarily involve copulation, and may indeed be due to some pathological condition of the individual whale. Omitting ovulation, then, the grouping of the South Georgia catch is limited to the pregnant and lactating and resting whales, of which the full analysis for five seasons is shown in Table II.

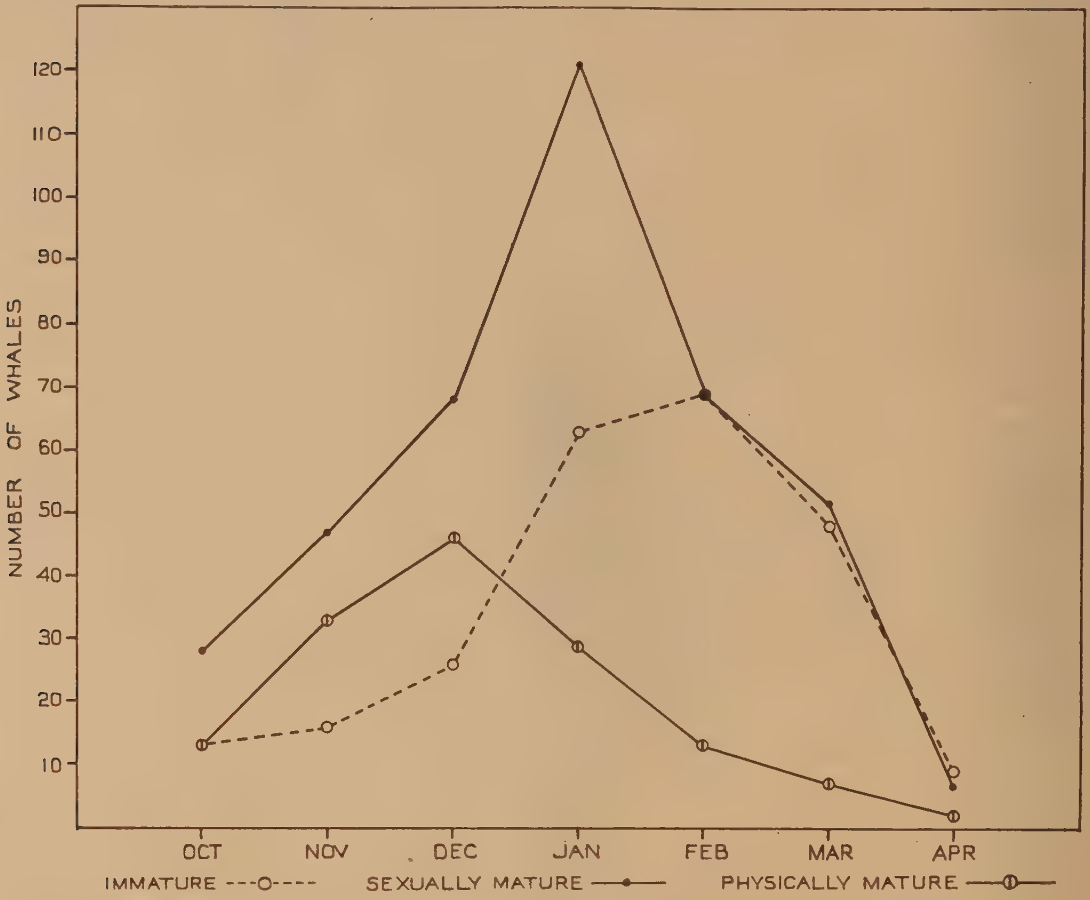

Fig. 1. Fin whales, females. Numbers of immature, sexually mature but not physically mature, and physically mature whales in five complete seasons at South Georgia.

Table II

Female Fin whales

Number of corpora lutea	1–4			5–9			10–14			15–19			20–24		
Years from sexual maturity	1–2			3–4			5–6			7–8			9–10		
Pregnant (*p*), lactating (*l*), resting (*r*)	*p*	*l*	*r*	*p*	*l*	*r*	*p*	*l*	*r*	*p*	*l*	*r*	*p*	*l*	*r*
1925–26	5	—	14	15	3	8	6	4	5	3	1	3	3	1	—
1926–27	1	—	3	2	—	1	5	—	1	2	1	1	—	—	—
1928–29	20	2	10	10	1	3	8	1	5	8	3	—	1	—	1
1929–30	40	4	8	27	8	7	14	4	3	17	4	3	12	8	4
1930–31	19	2	2	6	1	3	11	—	5	6	1	—	5	1	1
Totals	85	8	37	60	13	22	44	9	19	36	10	7	21	10	6
Totals in 1-year groups ...	85	45		60	35		44	28		36	17		21	16	
Totals in 2-year groups ...	130			95			72			53			37		

Number of corpora lutea	25–29			30–34			35–39			40–44			45–49		
Years from sexual maturity	11–12			13–14			15–16			17–18			19–20		
Pregnant (*p*), lactating (*l*), resting (*r*)	*p*	*l*	*r*	*p*	*l*	*r*	*p*	*l*	*r*	*p*	*l*	*r*	*p*	*l*	*r*
1925–26	3	—	—	—	—	1	—	—	1	—	—	—	—	—	—
1926–27	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
1928–29	2	—	—	1	—	1	—	—	—	—	—	—	—	—	—
1929–30	12	—	4	5	—	1	1	—	1	1	—	—	—	—	1
1930–31	6	—	—	1	—	—	—	—	1	—	—	—	—	—	—
Totals	23	—	5	7	—	3	1	—	3	1	—	—	—	—	1
Totals in 1-year groups ...	23	5		7	3		1	3		1	0		0	1	
Totals in 2-year groups ...	28			10			4			1			1		

The totals under each two-year period show a progressive reduction, as was expected, and in this there seemed to be the promise of a formula expressing the rate of reduction. All the stations at South Georgia dip into the same stock since the catchers from all the stations work the same grounds; it is safe therefore to assume that the catches at all stations are similar in composition and show the same rate of reduction. If the total catch from the area could be analysed it would consist of the same age groups represented by larger numbers of individuals, but the numbers would bear the same relation to one another, i.e. the rate would be the same. I wish to make clear the fact that this rate of reduction is not a local phenomenon; it is not confined to the catch of the Pesca company, neither is it increased when the activities of the other stations are taken into consideration. It is the rate at which the stock has been reduced, at South Georgia or elsewhere, by hunting, by natural death, disease or any other cause of elimination.

The validity of the rate of reduction, granting the acceptance of the method of age determination, depends upon two postulates, (i) the annual recurrence of the same stock to these waters, and (ii) the representativeness of the sample considered. Both of these difficult questions are discussed later on. It will be noticed that up to the present they have been taken as facts. As to the sample, i.e. the catch, one source of error has been pointed out and eliminated by the omission of the figures for the partial seasons 1924–5 and 1927–8. A further possible difficulty has been brought to light by the analysis into one-year groups. Throughout these figures a serious shortage of lactating and resting whales is evident. As regards the former an artificial check on the numbers captured lies in the protection by law of female whales running with calves, though I think that the whaling community would agree that unless a calf is present it is not possible to distinguish a lactating whale at sea and certainly a number are brought in to the stations. With females in the resting condition there is no such explanation and the fact can only mean that a certain proportion of whales in the post-pregnant condition do not accompany the main migratory schools, or, at all events, they do not appear on the South Georgia grounds during the fishing season. Is this, however, a serious drawback to the calculation of a rate of reduction? Fewer lactating whales may mean that the fishery falls more heavily upon the pregnant whales but it would appear from the figures that the proportion of absent females of each age is approximately constant. In the first five age groups the percentage pregnant is 65, 63, 61, 68, and 57. Pregnant whales can be considered as a two-year series, apart from lactating and resting whales, and these latter if fully represented should make another series. The numbers in the former series are not large, and as has been said, those in the latter are reduced by the operation of the regulations of whaling to still smaller numbers. Probably owing to the paucity of data, neither series exhibits a constant rate of reduction. Since, however, the total number in each of the first five age groups of Table II is made up of pregnant whales on the one hand and lactating and resting whales on the other in approximately constant proportions, it seems legitimate to treat the data in the age groups of that table as representative, notwithstanding the fact that the condition of the whales in each group is not homogeneous. Fig. 2 illustrates the reduction of stock as unanalysed and in the light of the conditions found within the various groups.

We now come to consideration of the series of numbers, 130, 95, 72, 53, 37, 28, 10, 4, 1, 1 which represents the number of females taken during five seasons which could be allocated into successive two-year age groups.

Edser's conclusions and comments may be summarized as follows: The series of numbers suggests the terms of a geometric progression of the form

$$ar,\ ar\,(1-r),\ ar\,(1-r)^2, \ldots$$

where a represents the initial stock of mature females and r the rate of reduction.

Dividing each term by its predecessor the factor $1 - r$ is left, and thus between the first six age classes (3–4 years to 13–14 years) the rate of reduction r has an average value of 26 per cent, the actual figures being 27, 24, 26, 30 and 24 per cent. Beyond the 13–14 year class the rate of reduction is greater—64, 60 and 75 per cent. For the first six age classes the reduction is therefore regular, as if it were due to one source of loss, but beyond 13–14 years the high reduction rates suggest that there is some other cause which removes the older whales from the South Georgia population, or, perhaps more likely, that the old whales do not linger in these waters. They may even avoid the locality altogether on their way farther south.

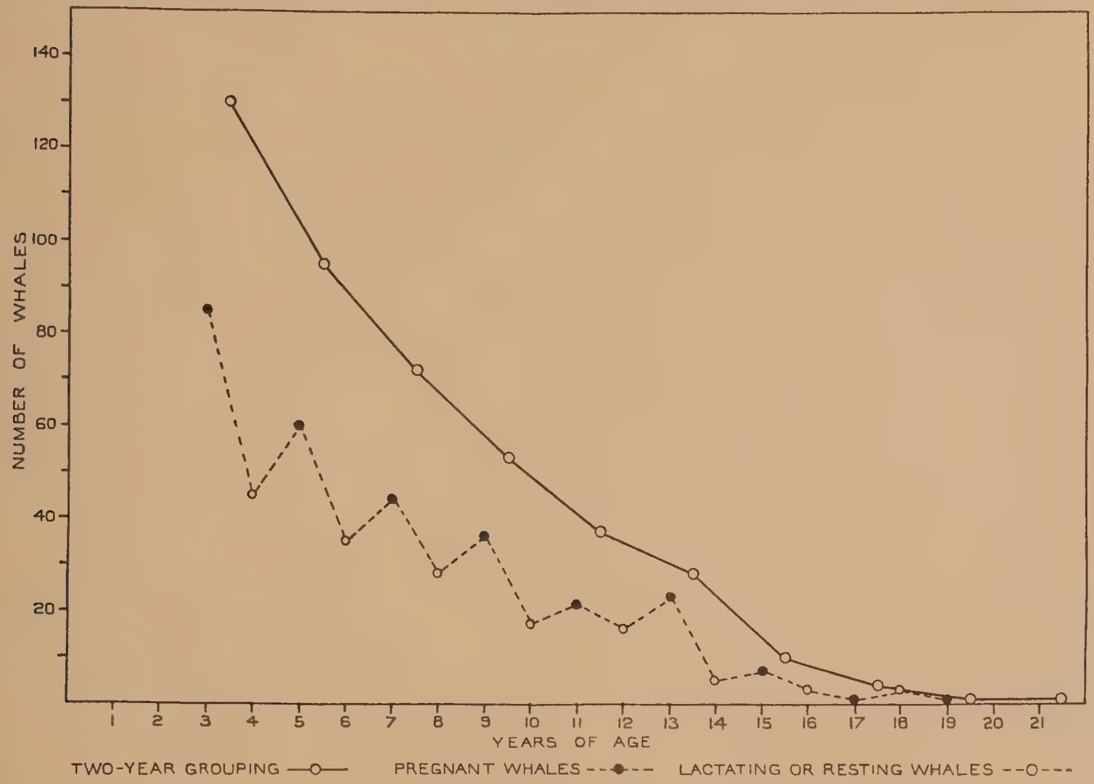

Fig. 2. Fin whales, females. Numbers of each age group in the total catch of five seasons: mature whales only.

Edser further calculates from these figures the number of immature females that must become mature in order to keep the stock at a constant level, and also the number of young females that can, in the most favourable circumstances, be produced by the mature stock.

By equating the sum of the first six terms of the algebraic series to the sum of the first six catches[1] a has been calculated, and with a equal to 497 and r to 26 per cent the theoretical catches based on the series and the stocks of whales in the corresponding age classes have been determined. These are given in Table III, in which it will be noticed that the only actual figures are those in column 2, those in columns 3–8 being theoretical. It will be seen how closely the theoretical catches in column 3 agree with the actual catches in column 2. By extending the series backwards for one term the theoretical catch and stock of immature whales have been determined.

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[1] $0{\cdot}26a\left(\frac{1-(1-0{\cdot}26)^{6}}{1-(1-0{\cdot}26)}\right) = 415$, i.e. the sum of the first six terms of the actual catch: from which $a = 497$.

Table III

Female Fin whales

1	2	3	4	5	6	7	8
	Figures for five years					Average figures for two years	
Age, years from birth	Actual catch	Theoretical catch	Theoretical stock	Surviving stock	Stock absent from South Georgia	Stock at South Georgia	Total stock*
0–2	—	(175)	(672)	(497)	—	(269)	(269)
3–4	**130**	129	**497**	368	—	147	147
5–6	**95**	96	368	272	—	109	109
7–8	**72**	71	272	201	—	80	80
9–10	**53**	52	201	149	—	60	60
11–12	**37**	39	149	110	—	44	44
13–14	**28**	29	110	81	43	15	33
15–16	10	—	38	28	13	6	24
17–18	4	—	15	11	7	2	18
19–20	1	—	4	3	0	1	13
21–22	1	—	4	3	—	—	10
			Totals for three years and upwards...			464	538

* Figures based on the assumption that the normal rate of reduction (26 per cent) is continued with the older whales.

Column 5 shows the numbers of whales in each age class that are not caught (stock minus catch). As far as the 13–14 year class the calculated stock in each age group is the same as the number of whales surviving in the previous age group. Beyond the 13–14 year class, where the series no longer holds, the stock has been calculated from the individual figures of the catch on the assumption that the catch is 26 per cent of the stock, and the figures obtained, by subtraction from the surviving stock of the previous age group, lead directly to the numbers of whales that have disappeared. It should be remembered that the whales missing from one age group do not appear in the stock of the next group. The numbers of missing whales are shown in column 6 (column 5 minus the next line of column 4). The absence of about half the older stock (52, 48 and 46 per cent are the figures) is a curious phenomenon whose implications have already been remarked upon.

All these figures are based on the catch for five seasons and it is necessary to find out how many whales can be produced by the remaining stock in two years, since each female gives birth normally to one whale in this period. This number is readily obtained by taking two-fifths of the mature whales which survive catching and are not absent from the catching area for other reasons, i.e. two-fifths of column 5 minus column 6. The numbers for each age class are given in column 7 and the sum—464—represents the number of whales of both sexes that can, in the most favourable circumstances, be produced by the mature stock. Roughly 232 of these will be females.

Now the theoretical stock of immature females for five seasons has already been worked out and two-fifths of this number (269) gives the initial immature stock for two years. It follows, therefore, since 269 immature females are necessary to keep the stock at its present level and only 232 females can be produced, that considerable damage is being done.

If, however, the older whales that are absent from the South Georgia population are not eliminated, but are still adding to the immature stock and are subject elsewhere to the same rate of reduction, the total of surviving mature females will be considerably greater. In column 8 the numbers of surviving stock of the different age classes are given supposing that no whales are missing; and the number of immature females produced—269, half the sum of this column—will just balance the losses and the stock will remain stable. It should be remembered that the figures for the reproduction of the stock are optimum values and that probably the conditions necessary to attain them are never reached.

While again stressing the indicative rather than the exact nature of the results it appears probable that on these lines some definition can be given to the effect of the fishery upon the whale population in this area.

A more difficult question is that of the killing of immature whales. The number of immatures in the South Georgia catches has been lately remarked on by Hjort, Lie and Ruud (1932)—"Why is it that in certain areas, especially where whaling has gone on for 25 years (from the old land stations) there are larger numbers of young animals than elsewhere? We cannot infer that more young animals are caught on the old grounds because the stock has decreased...it appears more likely that the young animals have a migration route or area of distribution of their own, which does not quite coincide with that of the adult whales".

The sexually immature females formed 32 per cent of the total catch examined by us, which is, on the face of it, an alarming proportion, if, as we have supposed, all the immatures are between the ages of one and two years. Up to the present we have had no method of age determination among the immatures except that afforded by deduction from length frequency. By utilizing such evidence as was available in 1928 the life history up to the time of sexual maturity was suggested by us as follows (Mackintosh and Wheeler, 1929, p. 444). Birth takes place at about 6·5 metres. Weaning at about 12 metres some six or seven months after birth in early summer when presumably mother and calf have migrated southward during the spring. On the analogy of the rather more complete evidence for the Blue whale there follows another migration northward and southward, at the end of which the whales are verging upon sexual maturity and again migrate to the north for breeding, i.e. two age groups should be present in southern waters, one of whales just weaned, the other of whales "verging on maturity". Representatives of the first group should not appear at all in the catches for mothers and calves are protected. Therefore all the immatures taken should belong to one age group only.

Table IV

Length and scar ages of female Fin whales immature by examination or less than 20 metres

Number of scar ages			
1	2	3	4
12·90	17·10	19·90*p*	18·16
16·70	19·60*p*	19·30	
13·90	19·75*p*	18·90	
14·65	16·45	18·75*p*	
	19·65	19·70	
	19·10	19·65*p*	
	17·55	19·30*p*	
	16·90	19·00	
	18·45	19·50	
	17·70	19·55	
	18·30	19·90*p*	
	18·00	19·80*p*	
	19·30	19·30	
	19·80	19·23	
	14·10	17·00	
	17·75	19·85*p*	
	18·35	19·25	
	18·85	18·20	
	16·60	19·60	
	18·40	16·50	
	18·65	18·55	
	16·00	18·25	
	17·75	19·50	
	19·80	19·87	
	19·40	19·85	
	17·80	18·25	
	19·95*p*	18·20	
	16·93	19·00	
	16·15	16·30	
	18·50	19·55*r*	
	16·70	21·40	
	19·05	19·20	
	17·95	19·65	
	17·95		
	16·25		
	14·60		
	17·10		
	18·10		

Note: *p* = pregnant; *r* = resting.

Some data collected during season 1929–30 on the presence of different ages of white scars can be adduced in support of migratory movements, though the light they throw upon the age problem is at best uncertain. Leaving aside the mode of formation of the pits and scars (Mackintosh and Wheeler, 1929, pp. 373–9) there remains the fact that whales caught off South Georgia are without exception scarred to a greater or less extent, while those caught in northern waters show the earlier stages of open or crescent pits (Olsen, 1913; Risting, 1928; Mackintosh and Wheeler, 1929). Every northern migration, then, adds a new batch of open pits, and the whales taken during the southern migration show a fresh series of white scars which can often be distinguished from the older scars by their whiteness, the depth of the central depression and by the fact that a new scar sometimes covers an older one in which the pigment has partly returned and the depression filled out. Naturally the more series that are superimposed one upon another the more difficult it is to estimate the number. Evidence of this kind is unsatisfactory in character since it depends largely upon observations of an indefinite quality; but the difficulties of obtaining any sort of evidence regarding age warrant its inclusion. There are listed in Table IV the lengths of individual female Fin whales, immature by examination or less than 20 metres in length (the critical length of sexual maturity) taken during season 1929–30, with the recognized ages of scars present.

The fact that the scarred condition of all the whales caught at South Georgia is proof of a north to south migration has been pointed out by Harmer (1931, p. 107). The further inference that the whales have migrated back and forth is not really proved since there are no data concerning the possibility of successive ages of scars made during a prolonged sojourn in northern waters. In this list there is confirmation of the first migratory movement in the presence of newly weaned or still lactating calves, which have come from the north as their scars bear witness.

If the connection between scar ages and migration is allowed the whales with two series of scars should have been twice in northern waters and twice south, i.e. they are the "immatures verging upon sexual maturity". What then of the group with three ages of scars, of which many are still immature? This suggestive point can be carried further by plotting the length frequencies of all the whales and differentiating between the age series of scars. This has been done in Fig. 3, which brings together all the data collected in 1929–30 relative to the ages of scars. Doubtful readings are omitted; but where the recorded ages were "three or more" the whales have been added to the fourth graph (four recognized age series and over). Two hundred and fifty-one female Fin whales are represented out of the catch of two hundred and seventy-two.

The group of whales with four and more age series of scars has been at least four times in northern waters and four times south if the correlation between scar series and migration is allowed. With one exception all are mature according to expectation. Of the whales that have apparently made three migrations south the majority are mature, but there are sufficient immatures to justify the statement that, on this evidence, by no means all female Fin whales become mature two years from birth. Therefore the group of "immatures verging upon maturity", considered up to now as a single age group, may be really composed of two groups, and the younger of these groups is from the appearance of the graph composed of somewhat smaller whales than the older. This to some extent corroborates the inference that two groups are present. The mature whales with two age series of scars can be explained on the assumption that they missed a northward migration, or alternatively, that they made a prolonged stay in the north so that it is difficult to tell where an older scar series left off and a newer one began. It is, in fact, possible to find a feasible explanation for a number less than the theoretically correct number of superimposed age series: it is more difficult to explain the capture of immature whales with a greater number of age series than their physiological condition warrants, unless they really are of greater age.

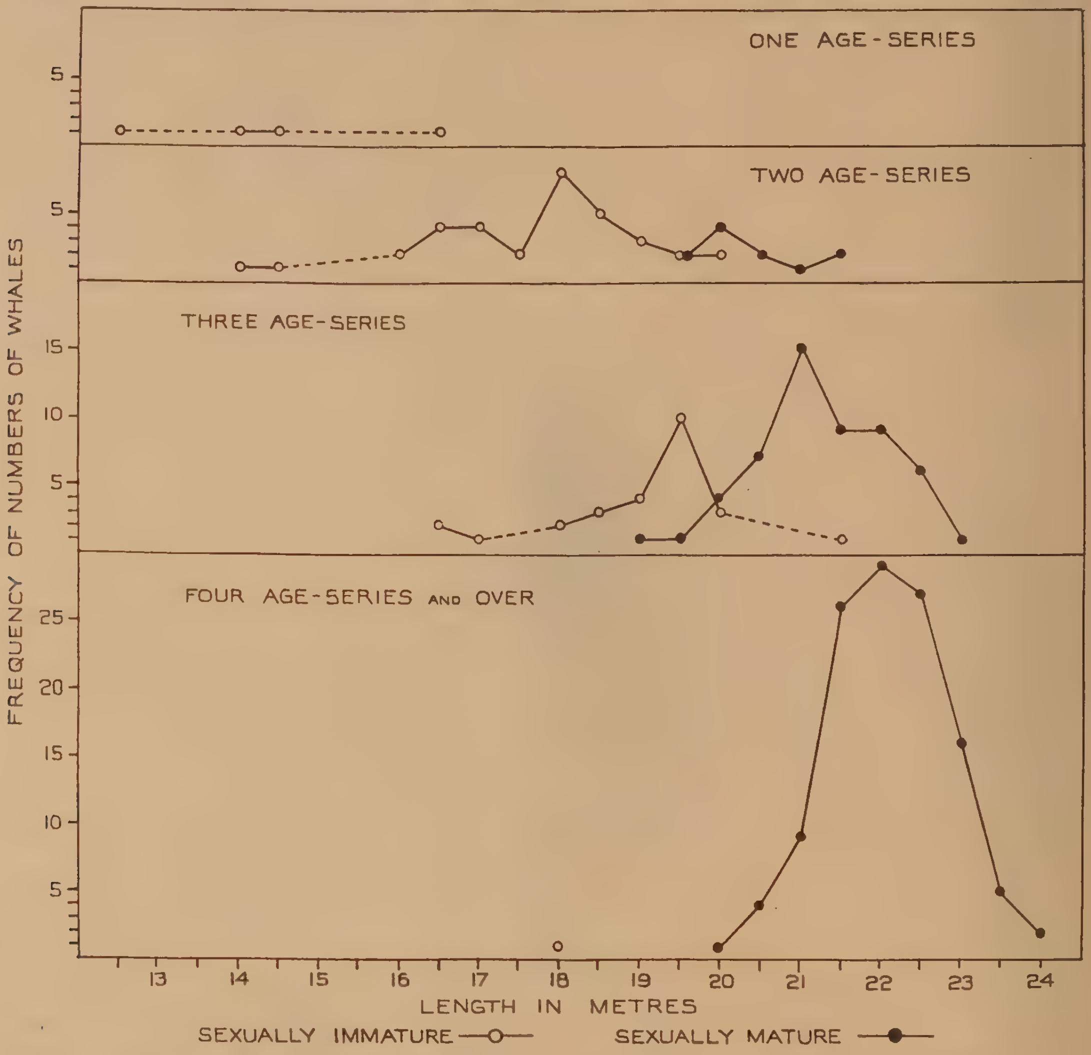

Fig. 3. Fin whales, females. South Georgia, 1929–30. Length frequency in half-metre length groups and number of age series of scars.

While therefore the foregoing cannot be advanced as proof of the contention, it does suggest that the apparent disproportion between the catch of sexually mature and immature females may be capable of a natural explanation on the ground of mixed ages rather than on the hypothesis of excessive fishing of a single age group comprising the immature whales.

If some female whales become mature at two years from birth and some at three the subsequent ages will also vary by one year and the determination of age after maturity by the corpora lutea is involved in this complication. Previously the addition of two years to the number of years from sexual maturity gave the age from birth, but on the new evidence whales pregnant with from one to four corpora lutea may be either two or three years old, those lactating with the same number of corpora lutea either three or four years old, instead of two and three years from birth respectively. Similarly with the later groups in the form of a double series. The rate of reduction is unaffected, but it treats two years as one, in that pregnant whales may be actually of the same age from birth as lactating whales and lactating whales as pregnant whales if they differ in series. Physiologically the age is the same, as also is the actual age starting from sexual maturity. The rate of reduction then is artificial in that its starting point is physiological and it does not take into account the years preceding sexual maturity.

The uniformity of the curve of reduction is the most striking argument in its favour, but it applies only to mature whales. The immatures cannot be added to the graph of reduction nor can the figures be considered with those of the mature whales. The reasons are not far to seek. There are 126 mature whales whose age is not known, which, because they formed part of the catch, should be included in the figures, as against only four whales believed to be immature on account of their length; also there is uncertainty in the number of ages represented by the 281 immatures as has just been deduced from the evidence of the scars.

Considered broadly our figures suggest a population unduly weighted with immatures and with pregnant whales, and we have now reached the point when general consideration of the catch and stock becomes all important: How far does the season's catch represent the stock and what evidence have we concerning the recurrence of the same stock at South Georgia?

Considerable changes have taken place in the South Georgia fishery during the twenty-seven years of its existence. Until 1907 the company founded by Larsen worked alone and made large catches of Humpbacks and Southern Right whales. Matthews (1931) says—"He (Larsen) arrived at Grytviken in December, 1904, and at once started work. Whales were plentiful and undisturbed, for months his catcher did not leave Cumberland Bay, as she was able to get all the whales that could be dealt with close inshore". These were the conditions that attracted other ventures in 1907, '08 and '09, with the result that in 1909–10 seventeen catchers were operating from a series of stations on the north side of the island forming a base line to the fishery roughly eighty miles in length. There were no restrictions. All species were taken when opportunity occurred, but few Sperms and Sei whales appeared in the catches and these species played no part in the later development of the industry. It is said that Right whales were abundant at the beginning of the fishery, but their number since that time has been small.

Humpbacks did not long figure in the catches to the practical exclusion of other species, for in 1912–13 they had become scarce and Blue and Fin whales were being hunted in their stead. This scarcity of Humpbacks caused considerable anxiety to the whalers, whose attitude is recorded in the following passage from the Magistrate's report on season 1913–14, "The question has often been debated by the local whalemen as to the real cause of this continual scarcity of the Humpback whale. Is it the continual killing that has thinned them down and frightened the remainder off? Or in the course of their ocean migrations have they merely changed their course for the time being to come back again? The general feeling is hopeful and inclined to take the latter view".

But the Humpbacks did not return and the companies swiftly adapted themselves to the new conditions. That there was a definite change of attitude is illustrated by the following extract from Barrett-Hamilton's general notes quoted by Hinton (1925, p. 155): "The species most hunted at South Georgia are Humpbacks, which are preferred to the Finners and Blue whales. A few Sperm and Right whales are caught, the former in November and December, the latter when amongst the other whales, but (according to Mr Henriksen, the manager of the South Georgia Company) usually they keep to themselves, north-west of the island, and are not worth hunting specially there. Though a Right whale is three times as valuable as a Humpback, the latter are preferred where abundant, because their size is convenient for handling. Similarly, Finners and Blue whales are not killed if Humpbacks can be obtained, being hard to kill and only manageable in fine weather. Blue whales are a bit too large for the tackle if adult. Therefore, South Georgia is primarily a Humpback fishery (Henriksen)". This was in 1913–14.

Blue and Fin whales then became the mainstay of the catch and since the beginning of this fishery the companies have been fortunate in that any improvements they introduced in the catchers and plant to meet the needs of the fishery with regard to one species met also its needs with regard to the other, and by drawing their catch from two species they were much less at the mercy of fluctuations in the supply of either. The failure of the Humpbacks, however, is a fact that cannot be ignored. There is no evidence at all that the course of their ocean migration was changed. It seems far more likely that the decline was due to overfishing, and if so it follows that it was the same stock that was affected each year.

The catches of Blue and Fin whales now claim our attention, and, limited as our knowledge is by lack of definite evidence of migrations, certain features of the supply of these whales can be outlined. It is evident from study of the catches that extensive movements of large herds of whales take place both into and out of the area. At one time fishing was continuous throughout the year but the catches made during the winter were far from profitable and it was realized as a fact of importance to the industry that of the large numbers of whales accessible during the summer only a small remnant remained round the island during the winter. The movements of the herds as deduced from monthly catch statistics have been studied by Risting (1928), and in more detail by Harmer (1931). It is shown that definite incursions take place but that the time of their advent is variable and usually divergent in the two species. In certain seasons the incursions are indicated in the graph of the catch as a single peak, showing that the supply increased for a time, reached a maximum and then declined; in other seasons there are two maxima separated by an interval of several weeks. As indicated by Harmer (1931, p. 110) certain localities are characterized by one or other type of season-graph, the study of which suggests that there are definite migration routes, probably not the same for both Blue and Fin whales, on which under certain conditions, again specific, the moving herds are delayed and the concentrations so profitable to the whalers occur.

The difference in the relative abundance of Blue and Fin whales is sometimes very sharply marked, and gives rise to the terms "Blue" season and "Fin" season, according to whether there is a great preponderance of one species or the other in the season's catch. These differences do not always occur, of course; sometimes both species are plentiful, sometimes both are scarce. The cause of these fluctuations is not thoroughly known, nor is it certain that the predominance of one species in the catch always indicates the true state of affairs in the catching area. If one species concentrates nearer the island than the other, the former will be the predominant one although the latter may be superior in numbers, because the catchers are, after all, concerned only with taking as many whales as they can as quickly as possible. The concentrations and movements of Fin and Blue whales have lately been the subject of a report by Kemp and Bennett (1932). The results obtained are based on returns made by the catchers, and, as the authors remark (p. 169): "When whales are plentiful in inshore waters the catchers will naturally not go farther afield, and we have evidently no means of knowing how abundant whales may be in the unexplored parts". It is shown that the main concentrations of Fins and Blues as plotted from the combined data of eight seasons (*loc. cit.*, pl. xxiii) are in remarkable agreement and that this agreement is correlated with an abundant food supply; but that in different individual seasons the positions of the centres of the concentrations differ greatly, some part of which is attributed by the authors to irregularities in the time of arrival of different schools of whales.

For many years the whalers have noticed that some form of correlation can be traced between the presence of Blue whales and the ice conditions. Risting (1930, pp. 56, 93 and 97) definitely connects the action of warm and cold currents upon the drifting pack ice with the growth of plankton and the occurrence of whales. Harmer (1931) discusses this question fully and correlates the September mean air temperature at South Georgia (closely connected with the events leading to the melting of the ice) with the order in which the two species reach their maximum in the catches of the season immediately following (p. 131); and by an examination of the records he shows that the species which is first in excess nearly always maintains its superiority in both halves of the season and in the total catch (p. 146).

We have then evidence from the catches that concentrations of one or other or both species are formed off the island, which vary both in position and in time, such variations being probably controlled by hydrographical and meteorological conditions. There is nothing here inimical to the idea of a closed stock of whales, i.e. a body of whales breeding in a certain area, migrating on a certain line and ending their food migration in South Georgian waters or passing through these waters on their way farther south. This idea indeed underlies the work on variation of seasonal concentrations just as it is implied in the following remark from Kemp and Bennett (1932, p. 179): "The considerable extension of the grounds during the recent four-year period, and the fact that with the same number of whale-catchers fewer whales have been taken, lends support to the generally held opinion that whales are now less abundant than formerly".

Drawing conclusions from the diminution in number of sexually mature individuals taken off South Georgia and the South Shetlands, Harmer (1931, p. 100) says: "Another conclusion which it seems legitimate to draw from these figures is that the whales do not wander at random throughout the Antarctic area, but are to some extent separated into assemblages which have preference for particular localities. If this were not the case, it would be difficult to account for the fact that the percentage of sexually mature individuals appears to be correlated with the length of the period during which whales have been hunted in a locality".

The same author (*loc. cit.*, p. 108), after discussing the evidence of movements of immature and mature whales, fat and lean whales and whales covered with diatom film and scars, draws the conclusion that "The various maxima noticed in the season-graphs are thus not necessarily due to the continued migration of a simple stock of whales. There is good reason for believing that they are, or may be, the resultant of a complex series of movements, partly of whales, often immature, from the north, and partly of well fed individuals moving northwards from their Antarctic feeding grounds".

Now the arrival of batches of whales at different stages of maturity has already been touched upon (p. 355), and a sequence of physically mature, sexually mature not physically mature, and immature in December, January and February has been demonstrated. This sequence may be simply an expression of the different rates of progress physically possible to the different sections of the community; for physically mature whales are, on the average, one metre longer than the rest of the sexually mature whales[1] and the latter are, of course, considerably longer than the immature. These differences coming into play on a long migration would be an efficient cause of segregation. There is, however, no evidence concerning this migration other than that already indicated by the heavily scarred condition of the larger whales. Against this there is the undoubted fact that batches of whales appear in the South Georgia catches covered with thick diatom film (Bennett, 1920), which suggests strongly a stay of some length in Antarctic waters.

There is evidence that in the early part of the season, when the influx would be expected from the north, Fin whales are more often than not moving in a northerly direction (Kemp and Bennett, 1932, p. 181).

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[1] The average length of 329 female Finners with less than fifteen corpora lutea is 21·41 m.; that of the remaining 143 mature whales is 22·41 m.

Collective differences between the sexes have also been recognized. Sometimes for a week or more the catch is made up almost entirely of male whales as it was in the early part of January 1926 (Mackintosh and Wheeler, 1929, p. 461); sometimes females are predominant; and it has been shown by Risting (1928) that males generally outnumber females in the total catches.

Segregation can be explained on the ground of physical differences between the sexes during the course of a long migration. It is not often possible to say which sex precedes the other on the grounds, but when the large numbers of immature male whales appeared in 1926, there was a suggestion, in the later arrival of immature females, that the former might have outstripped the latter in a migration from the same area.

There are two illuminating features regarding the prevalence of males in the catches. From the statistics of the British Museum (Nat. Hist.) it is recorded that males were slightly in excess of females at the South African stations as well as those of the Dependencies of the Falkland Islands (Mackintosh and Wheeler, 1929, p. 322). From the same statistics there is evidence that males outnumber females considerably in "Fin" seasons; while in seasons when Fins are scarce, generally, though not invariably, females slightly outnumber males. These indications point to somewhat different areas or methods of concentration of the sexes. The females may concentrate rather farther from the island or in a more diffuse form than the males. Probably also the females are more timid and easily scared by the hunters. In any event there is no reason to suppose that the catch of females is less representative of the ages present than the catch of males, unless deficiency of lactating and resting females is due to some local distributional factor at present unsuspected.

The apparent undue prominence of immatures in the catches applies to males as well as females and to Blues as well as Fins. The fact was commented on by Hinton (1925, p. 162) who, in dealing with the earlier years of the Blue and Fin fishery suggested that from his data, it appeared that the attacks of the catchers were being directed at adolescent Finners and sexually immature Blue whales rather than the adults, since they were easier to kill and certainly easier to handle with tackle designed for the Humpback. With the change of objective of the fishery came changes in design and power of the catchers and improvements in the tackle, so that Hinton's second reason for the excess of immatures is no longer applicable. There is no doubt, however, that immatures are easier to kill since they are not as easily scared as the older whales. Also they tend to run nearer to the coast and are thus more easily accessible. Both these reasons play their part in increasing the proportion of small whales in the catch.

In recapitulation let us investigate the catch of Finners taken by the Pesca company during a single season, using all the evidence at our command. In 1929–30 (a "Fin" season) the company captured 750 whales. Fifteen whales were taken before our arrival in South Georgia and nine were missed during the season. Our sample of 726 is therefore 96·8 per cent of the company's catch.

We examined 570 Fins of which 272 were female, and 70 of these females were sexually immature. From the mature females 189 ovarian records were obtained. The remaining 13 were decomposed to such an extent that the number of corpora lutea could not be determined with certainty. They were sexually mature, however, and we have to consider the immatures in relation to our full sample of 272; while the age series determined by the corpora lutea represents the distribution of age groups among 189 sexually mature whales. In Table V the percentages have been calculated as though the entire sample had been examined.

The percentage of immatures in our sample of the population is 25·7. Among them are five of small size (see Table IV), three of which had evidently not long been weaned. They were less than one year old. The other two had two series of scars, suggesting from this together with their size that they were very late calves of the previous season and were thus in their second year when killed. From the two series of scars marking 33 immatures, with one whale of 16·7 m. with one scar series, and the two small ones already noted, we have 36 whales more than one but less than two years old. Whales of nearly three years include 26 immatures as well as ten mature whales with two series of scars and 53 with three. The mature whales are, however, included in the estimations determined by the corpora lutea and we have already seen that 40 are nearly three or nearly four years old and twelve are nearly four or five. The apparent disporportion of immatures is now explained by the three successive year groups that are represented in the catch. The earliest of these can for practical purposes be neglected, for not only is the appearance of its representatives in the catch subject to penalty and only due to accident, but it is almost certain that the figure obtained conveys a wrong impression of the population. It is probable that large numbers of the newly weaned whales never make the migration and this explanation covers the shortage of lactating and resting whales of all ages which is a feature of the South Georgia catch. The large catches of immature whales made at Saldanha Bay, South Africa, suggest that many of the early calves are weaned and left in the coastal waters of the breeding areas, while late calves are weaned during migration or even after arrival in southern waters. In support of this I can point out that, although lactating whales are few, they are certainly more numerous in the catches at the end of the South Georgia season than at the beginning. This must not be taken to imply necessarily the identification of the South African whales with those of South Georgia. It is supposed, however, that similar conditions prevail wherever the breeding area may be.

The original group of "immatures verging on maturity", i.e. the immatures more than one but less than two years old, now form but 13 per cent of the sample catch. On returning to the north, many of this group will commence to breed and they will be accompanied on the next southern migration by the rest of the group (9½ per cent of the sample catch) which will not become mature until their return to northern waters in the following winter when they are just three years old.

With the aid of the estimations of age from Table II we can now sketch the relative age composition of our sample as follows:

Table V

Female Fin whales. Estimated age composition of the observed catch in season 1929–30

	Number	Percentage of sample (272)
Sexually immature females		
Less than one year from birth	3	1
More than one and less than two years from birth	36 } 62	13
More than two and less than three years from birth	26	9½
Sexually mature females		
More than three and less than five years from birth	40	14½
More than four and less than six years from birth	12	4½
More than five and less than seven years from birth	27	10
More than six and less than eight years from birth	15	5½
More than seven and less than nine years from birth	14	5
More than eight and less than ten years from birth	7	2½
Physically and sexually mature females		
More than nine and less than eleven years from birth	17	6
More than ten and less than twelve years from birth	7	2½
More than eleven and less than thirteen years from birth	12	4½
More than twelve and less than fourteen years from birth	12	4½
More than thirteen and less than fifteen years from birth	12	4½
More than fourteen and less than sixteen years from birth	4	1½
More than fifteen and less than seventeen years from birth	5	2
More than sixteen and less than eighteen years from birth	1	Less than ½
Remainder of the sample catch	4	1½
Total number of sexually mature females = 189		

The greatest damage inflicted on the population now appears to be spread over the period between the second and seventh year of life. There is, however, another way in which these results bear upon the question of depopulation. If it be allowed that sexually mature females produce a calf every two years and that every other calf is female, then in the distribution of the population shown in Table V the increment per two years of female calves more than one and less than three years from birth would be one quarter of the mature females, i.e. 47. But the rate of destruction is shown to be 62, so that on this evidence, in so far as Table V is representative of the stock, severe damage is being done. Shortage of old whales does not appear to have been a feature of season 1929–30, but the absence of lactating and resting whales is quite strongly marked. The numbers taken are too small to respond satisfactorily to mathematical treatment, and indeed, the figures that have been used in computing the rate of reduction must not be accepted too literally. Apart from the errors introduced by taking five seasons together there are probably more serious faults, due to the overlapping of the age groups, which are impossible to estimate. The conclusions must therefore be regarded as indicative of the state of affairs only.

The crux of the problem is the identity of the whales visiting the area in successive seasons. Only proof of identity can give value to the rate of reduction and it does not seem possible to obtain this proof indirectly. The failure of the Humpback fishery has been adduced as evidence to show the results of continual attack upon a closed stock, and although some of the data concerning Fins and Blues, especially as regards their movements and the presence of diatom film, appear antagonistic to the general theory of a recurrent population, there is, at any rate, a possibility that this population exists as an entity, and there the matter must be left until marking of whales on a large scale is successfully carried out.

SUMMARY

The whale population of the South Georgia area has been investigated in the light of evidence from the corpora lutea and scars on the epidermis.

The catch has been analysed showing that maxima of physically mature females occur in December, sexually mature not physically mature females in January, and sexually immature females in February.

Analysis of the age groups of mature whales determined by the corpora lutea over five seasons shows a rate of reduction of 26 per cent and a suggestion that the remaining mature whales, after this percentage is withdrawn, might keep the population at its present level notwithstanding a deficiency in numbers among lactating and resting whales. A shortage of the older age groups is demonstrated, which, should the missing whales be eliminated elsewhere, must lead to an adverse balance.

On evidence obtained from scars formed in northern waters it has been possible to divide the immature catch into three age groups.

The importance of definite evidence regarding the recurrence of the same stock in these waters is pointed out and the main features of the lines of research into this problem are put forward.

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